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SOME RECENT TESTS OF CONCRETE IN TENSION AND COMPRESSION AT THE COLUMBIA UNIVERSITY LABORATORIES.

By Ira H. Woolson,* M. Am. Soc. M. E.

The recent rapid increase in the use of concrete for all details of engineering and building construction has aroused a widespread desire for exact knowledge of its physical characteristics. This demand has naturally stimulated investigators of this country and of Europe, and much valuable research on plain and reinforced concrete has been accomplished, particularly in ascertaining its resistance to crushing, and its ability to carry a load when employed as a beam. As a result of this work on concrete, we have a fair idea of its merits for these two purposes. We are, however, still much in the dark regarding several other qualities, which are essential to a strictly intelligent use of this valuable structural material.

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The determination of standard values for strength and other physical properties of concrete is difficult, because all the factors in the problem are variables: First, the great variety in cement and lack of uniformity in any one brand of cement; second, the difference in quality of sand or crushed stone used as a substitute for sand; third, variation in the quality and size of the stone, gravel, slag or cinders employed; fourth, the variation in the amount of water added, the thoroughness of mixing and tamping, the age at which the concrete is tested, and last, but not least, the possibility for an almost endless number of proportions in the ingredients. With all these opportunities for a diversity of product, it is doubtful if any two experimenters on concrete ever worked on exactly the same material, and it is easy to understand the wide divergence in results. Strictly comparable data from tests can not be obtained until experimenters agree to standardize the composition, method of manufacture, and age of material—in fact, eliminate all possible variables and produce practically a standard concrete. Investigators realize the importance of this, and steps are being taken to obtain series of tests upon a strictly uniform mixture. Such work necessarily involves time, meanwhile the users of concrete will be much benefited if all reliable test data are made public, together with details of composition and methods of manufacture.

Pursuing this idea, the writer has prepared for publication the following information on a series of tests recently completed by him in the Testing Laboratory at Columbia University. He presents it to the readers of Engineering News, hoping it may prove an aid to some one seeking such information. The work was done for the Astoria Light, Heat & Power Co., and it is through the courtesy of this company that permission to make public the results is granted. The company is erecting at Astoria, Long Island, the largest gas plant in the world. In connection with this work one of the most formidable tasks which confronted the engineer of the company was the construction of a water-tight gas holder tank 300

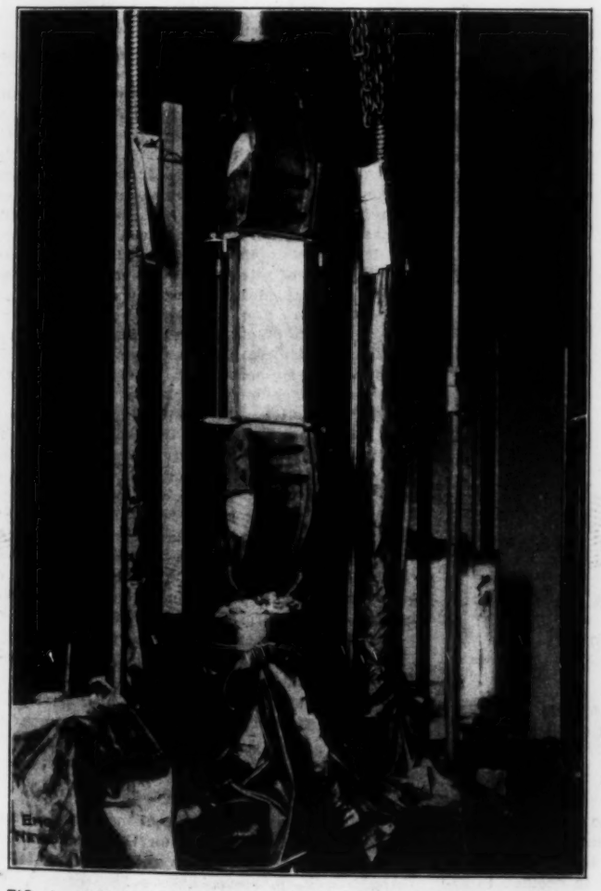


FIG. 1. CONCRETE BRIQUETTE ARRANGED FOR TENSION TEST.

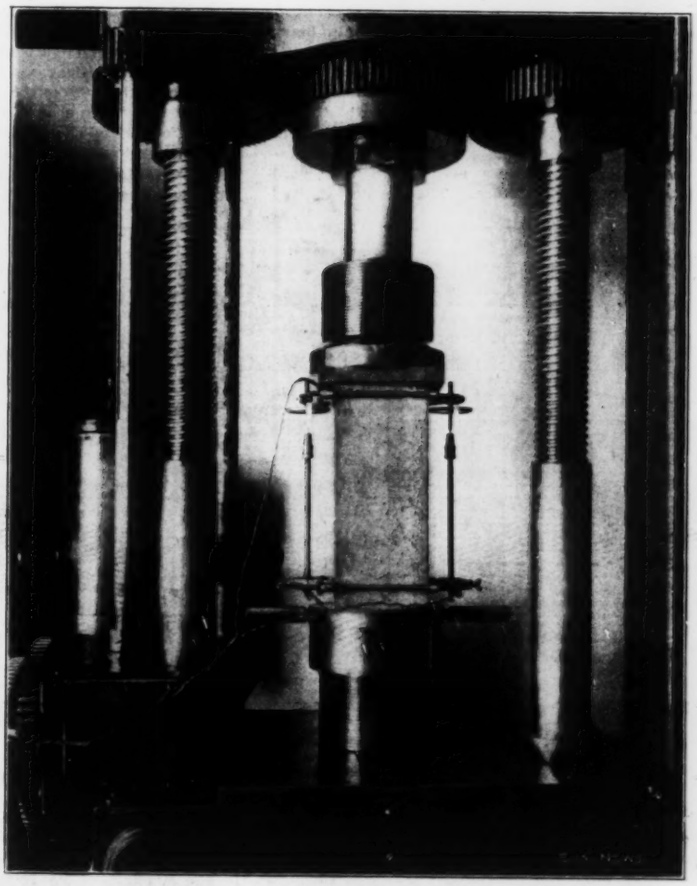


FIG. 4. CONCRETE BLOCK ARRANGED FOR COMPRESSION TESTS.

TESTING CONCRETE BLOCKS IN THE ENGINEERING LABORATORIES AT COLUMBIA UNIVERSITY.

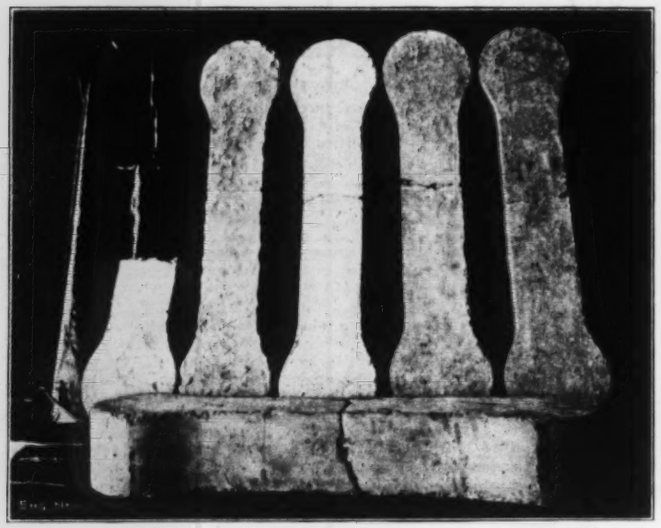


FIG. 2. VIEW SHOWING REGULARITY OF BREAKS IN CONCRETE BRIQUETTES.

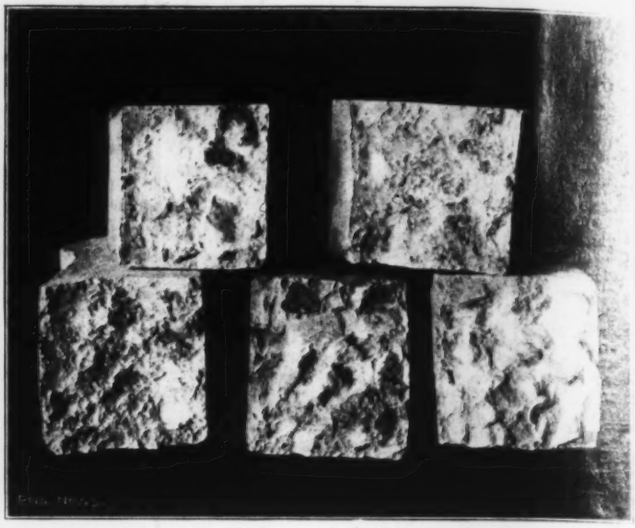


FIG. 3. END VIEWS OF BREAKS IN CONCRETE BRIQUETTES.

ft. in diameter and 48 ft. 9 ins. deep. Three forms of construction for this tank were considered: Riveted steel plate, a brick wall, and a reinforced concrete wall, the two latter methods requiring an excavation practically as deep as the tank.

An extremely careful analysis of the problem led to the adoption of the reinforced concrete construction. Taking into account the magnitude and the very permanent character of the work, it seemed to offer the cheapest and most satisfactory solution to the problem. The only hesitation in making the choice was due to a fear of possible lack of uniformity in the mixture. This uncertainty instigated an elaborate investigation upon cement mixtures. Over 4,000 tests of such mixtures were made by the company's chemist, before a ton of cement was used. The preliminary preparation for all the work was as thorough and complete as skillful engineers and liberal use of money could make it.

The desire to ascertain if the strength of concrete in mass could be predicated from the data of tests on small briquettes led to this investigation on large specimens made with full sized stone in regular mixture. The results showed that such a forecast would not be reliable. An interesting fact brought out by the study was that the strengths of small briquettes made with limestone screenings mixed as they came through a No. 4 sieve, i. e., fine and coarse, were practically the same as those of briquettes made from screenings which passed a No. 4 and remained on a No. 8 sieve. The dust apparently had no effect, so far as strength was concerned, but it did contribute to the density of the mixture, which would reduce porosity and lessen absorption.

The compression and tension tests here recorded were made upon plain concrete to determine the relative merits in the mixture, of a local sand and of limestone screenings. The elastic properties were also determined upon most of the specimens. The tensile strength was a matter of considerable moment, that being the stress to which the concrete would be subjected in the tank wall. Although reinforcing bars were required in the construction, it was desirable to know how much pull the concrete itself could withstand. The test specimens were briquettes 6 × 6 ins. in cross-section, with a total length of 3 ft. 6 ins. Special holders or clips were designed which gave excellent satisfaction, nearly all the specimens breaking in the middle third of the length. Figs. 1 and 2 show shape of specimen, form of holder, and uniformity of the fractures.

These tension tests are believed to be particularly valuable since they were made upon such large specimens, and in the tests where elastic measurements were made, the readings were taken to the breaking load in each instance. The first series of tests was made to determine the tensile strength only. It was then decided to repeat the tests and determine the elastic properties as well as the strength. This second lot of specimens was supposed to be identical with the first, but did not develop the same tensile strength. The cause of discrepancy was not apparent. The specimens were made the same in every particular, except that the stone was taken from a different shipment, though from the same quarry. A careful investigation of the quality of the stone was instituted by the company's chemist, from which conclusions have not yet been drawn. A third duplicate set of specimens was prepared to check the other two and the tests gave results which were practically a mean between the first and second. The values for all these tests are given in the tension column, Table I. The reason for this variation in strength is still uncertain. The uniformity of the cement was reasonably assured, the crushed limestone was the same in all. The quality of the broken stone may have had some influence, though it is doubtful. It is known that different men mixed these duplicate lots, and the personal equation of these men may have caused the variation in the product. There is also a possibility that the difficulty arose from the fact that in making the tests on the first lot, the load was applied continuously until the specimens broke, the time occupied being about five minutes. The elastic properties were determined in the later tests and the load was applied by increasing increments, with a period of release between each application, the time occupied by a test varying from one-hour to one and one-half hours. Whether this repetition of stress and release produced a weakness is uncertain; later tests both ways do not appear to support such a theory, though there were scarcely enough duplicate tests made to settle the question.

It was found that when the load was released for measuring the set deformation, the specimen did not immediately recover its equilibrium, but required a little time. At least one minute was always allowed after release of load before set deformation was read. Experiments indicated that a longer time was not necessary, no appreciable change taking place after the expiration of one minute. This sluggishness occurred in both tension and compression tests.

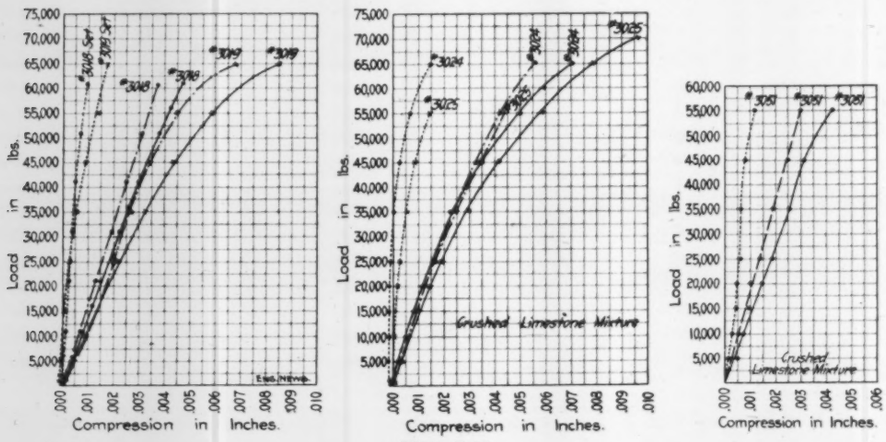
The mixtures were all in the proportion of 1 Portland cement, 2 sand or crushed limestone, and 4 broken limestone.

The preliminary small briquette tests previously mentioned, gave the following average strengths:

Briquettes, 1 cement, 3 sand.	Briquettes, 1 cement, 3 crushed lime stone.
7 days = 175 lbs.	7 days = 345 lbs.
28 " = 249 "	28 " = 461 "

The sand was a fair grade of moderately sharp sand which was available on the site. It contained less than 1% of loam and all passed freely through a ⅛-in. sieve. Above 75% of it would pass a 20-mesh sieve.

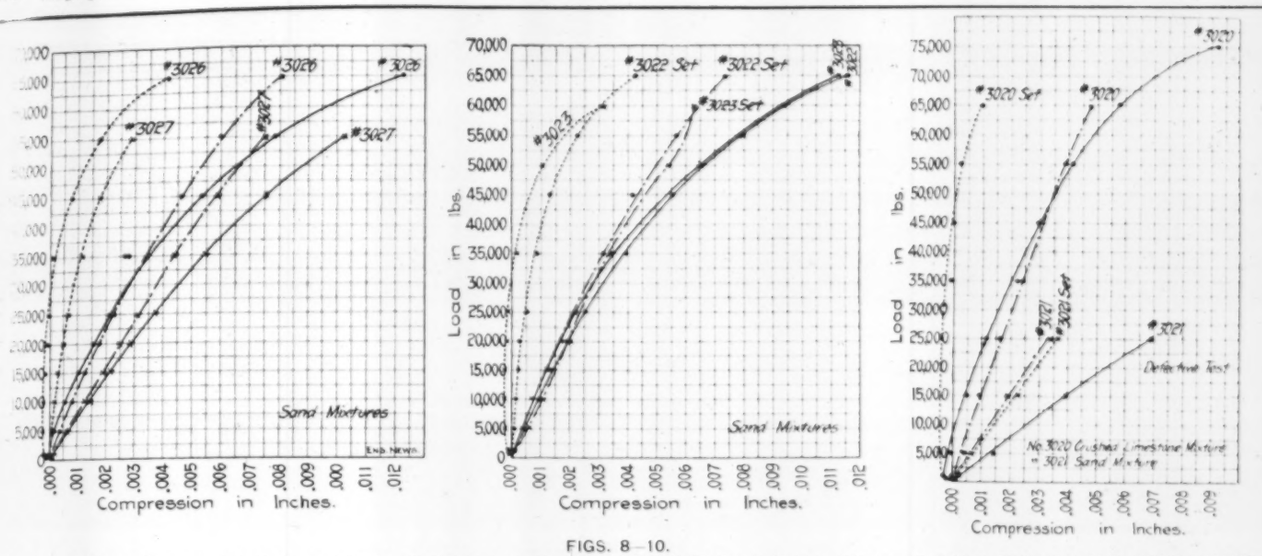
The limestone was a Hudson River bluestone



FIGS. 5—7.

DIAGRAMS SHOWING SET CURVES, ELASTIC CURVES, AND TOTAL DEFORMATION CURVES OBTAINED FROM TENSION AND COMPRESSION TESTS OF CONCRETE AT COLUMBIA UNIVERSITY LABORATORIES.

Legend.—Dotted lines indicate set curves; dot and dash lines indicate true elastic curve; full lines indicate total deformation curves.

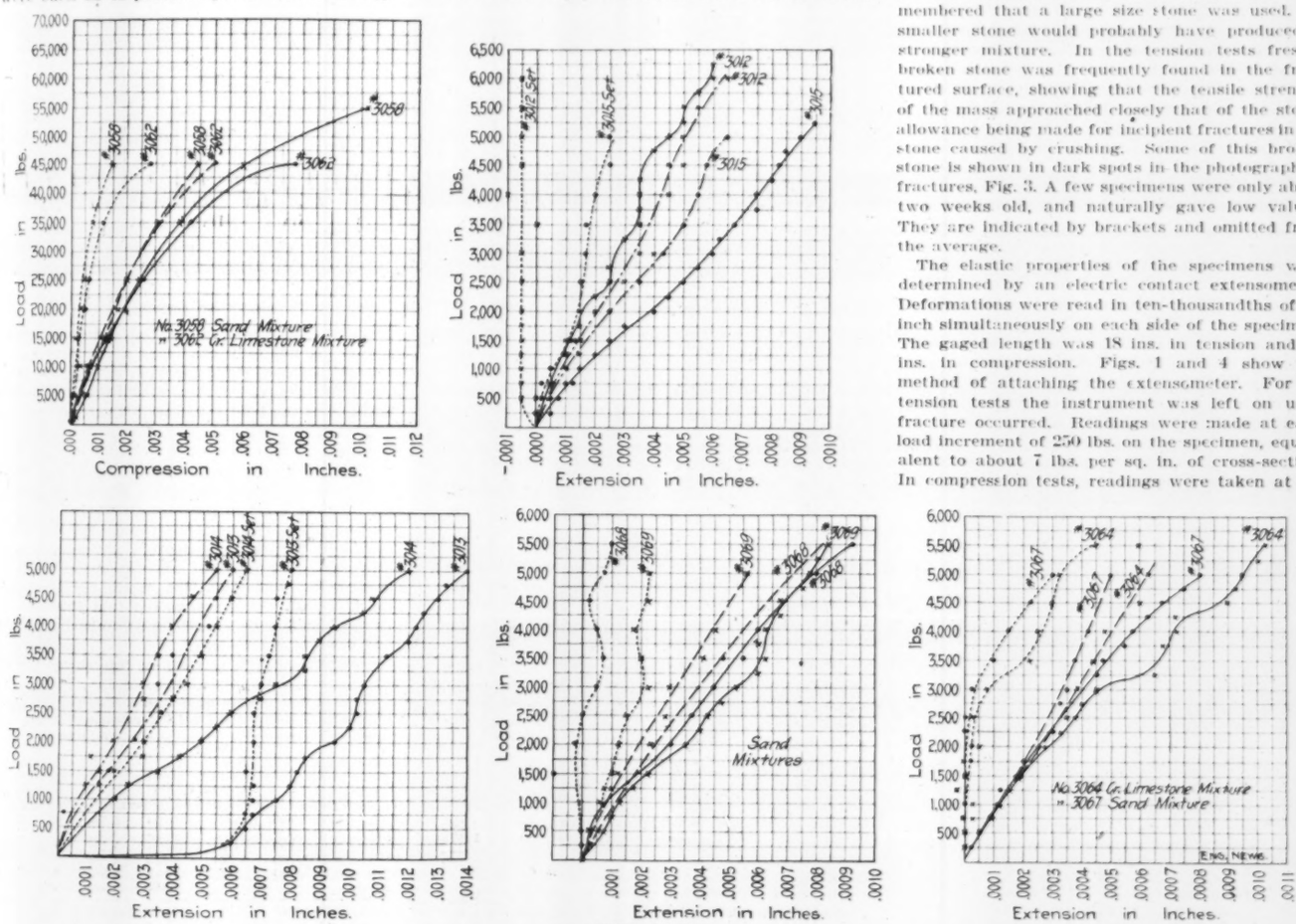


FIGS. 8—10.

DIAGRAMS SHOWING SET CURVES, ELASTIC CURVES, AND TOTAL DEFORMATION CURVES OBTAINED FROM TENSION AND COMPRESSION TESTS OF CONCRETE AT COLUMBIA UNIVERSITY LABORATORIES.

Legend.—Dotted lines indicate set curves; dot and dash lines indicate true elastic curve; full lines indicate total deformation curves.

and was of clean uniform quality. That which was used instead of sand was ¾-in. crusher screenings. The proportions of fine sizes and dust were such as to practically fill the voids; 87% of



FIGS. 11—15.

DIAGRAMS SHOWING SET CURVES, ELASTIC CURVES, AND TOTAL DEFORMATION CURVES OBTAINED FROM TENSION AND COMPRESSION TESTS OF CONCRETE AT COLUMBIA UNIVERSITY LABORATORIES.

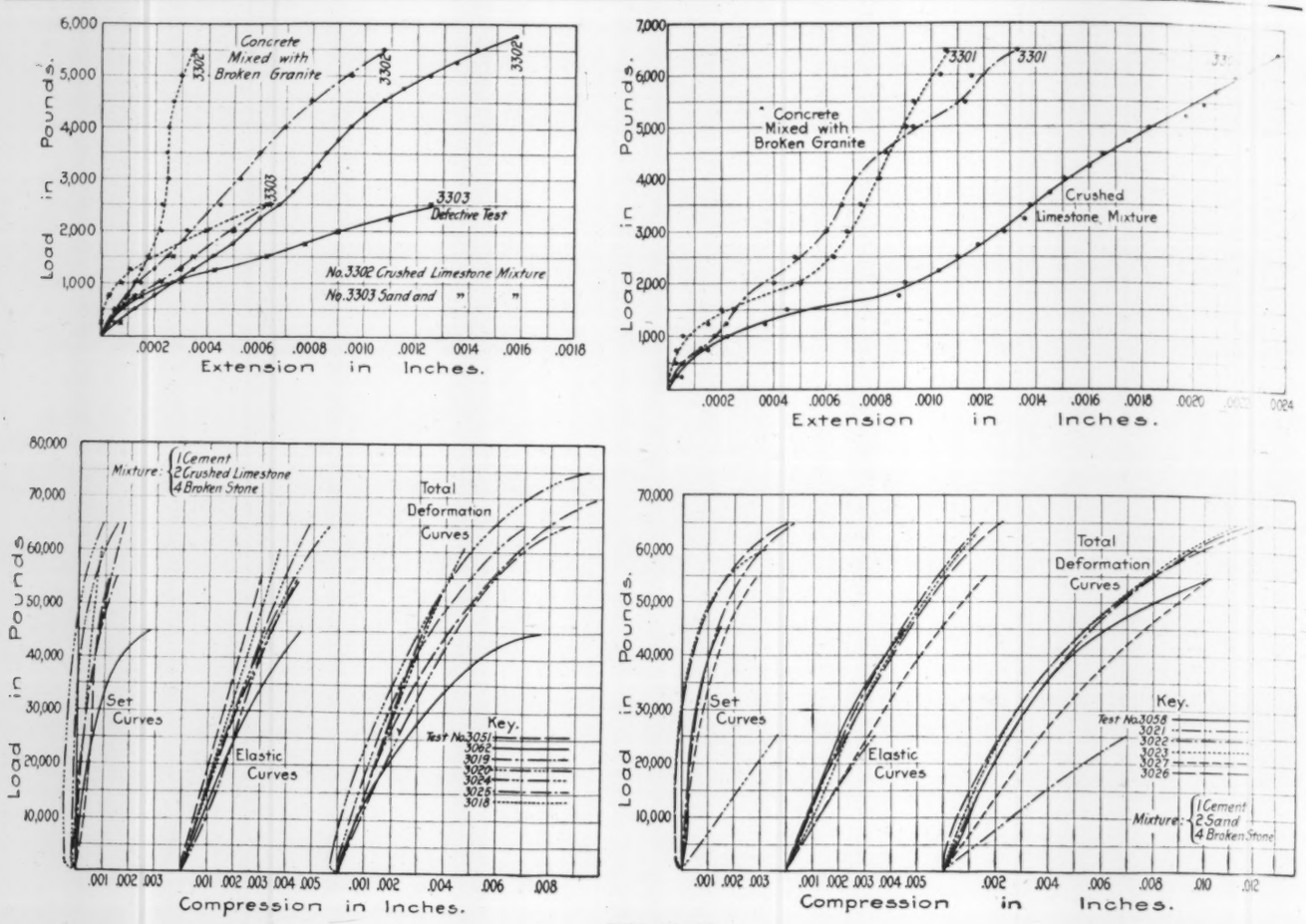
Legend.—Dotted lines indicate set curves; dot and dash lines indicate true elastic curve; full lines indicate total deformation curves.

it passed a ¼-in. sieve, and 40% passed a ⅛-in. sieve.

The broken stone was known as 2-in. stone, but a test proved that it would practically all pass a 1½-in. screen, and all remain on a ⅜-in. screen. The concrete was carefully tamped into the molds in a moderately wet condition, allowed to set one or two days, then immersed in water for five or six days, afterwards air dried for about four weeks before test. In a few instances seven weeks elapsed before test.

Table I. gives the strength of all the specimens and demonstrates conclusively that the crushed limestone gave a stronger combination than the sand, although the superiority was not nearly so marked as might be expected from the data obtained from the small briquette tests. In noting the strength per square inch, it should be remembered that a large size stone was used. A smaller stone would probably have produced a stronger mixture. In the tension tests freshly broken stone was frequently found in the fractured surface, showing that the tensile strength of the mass approached closely that of the stone, allowance being made for incipient fractures in the stone caused by crushing. Some of this broken stone is shown in dark spots in the photograph of fractures, Fig. 3. A few specimens were only about two weeks old, and naturally gave low values. They are indicated by brackets and omitted from the average.

The elastic properties of the specimens were determined by an electric contact extensometer. Deformations were read in ten-thousandths of an inch simultaneously on each side of the specimen. The gaged length was 18 ins. in tension and 12 ins. in compression. Figs. 1 and 4 show the method of attaching the extensometer. For all tension tests the instrument was left on until fracture occurred. Readings were made at each load increment of 250 lbs. on the specimen, equivalent to about 7 lbs. per sq. in. of cross-section. In compression tests, readings were taken at intervals of 5,000 lbs. equal to about 140 lbs. per sq. in. of section, except at the start when readings were made on 250-lb. loads. The instrument was left on the specimen as long as seemed prudent with each test.



FIGS. 16—19.

DIAGRAMS SHOWING SET CURVES, ELASTIC CURVES, AND TOTAL DEFORMATION CURVES OBTAINED FROM TENSION AND COMPRESSION TESTS OF CONCRETE AT COLUMBIA UNIVERSITY LABORATORIES.

Legend.—Dotted lines indicate set curves; dot and dash lines indicate true elastic curve; full lines indicate total deformation curves.

Figs. 5 to 17 are the curves as plotted for the original reports, usually two on a sheet. In order that tension test curves might appear in a size convenient to study, they were plotted to a scale ten times as large as the compression curves.

Professor Bach's method of finding the true elastic curve has been followed, and three curves are plotted for each test. First, the curve representing the total deformations; second, the curve of sets, and third, the elastic curve which is obtained by subtracting the second from the first. This appears to be the most rational method of diagramming the work as the resultant elastic curves are uniform in character and free from many irregularities common to the original working curves.

The curves in each figure are from specimens of the same composition except Figs. 10, 11, 15 and 16, which are mixed. Figs. 18 to 22 are a summation of the individual curves into groups, according to composition of specimens and nature of test. They furnish opportunity to study the general tendency of each group in comparison with others.

The coefficient of elasticity (E) was calculated from three points on the elastic curve for each specimen. Table II. gives the summary of the results. It not only furnishes a fair idea of the value of the coefficient for each mixture, but also shows the general tendency of the coefficient to decrease as the load increases. There were a few exceptions to this rule, the reason for which is not apparent. The value of E for any specific mixture does not appear to be controlled by variations in the ultimate strength. The average value of E for the crushed limestone with broken-limestone mixture, was not far from 5,000,000 and was practically the same in tension and compression. With the sand mixture, the average value in compression was 3,600,000, while for tension it was 4,500,000. It is recognized that these figures are not based upon a sufficient number of tests to yield definite conclusions.

In published data of tests of this character, the

TABLE II.—MODULI OF ELASTICITY (E).

Figured from the Elastic Curve.

("Elastic Curve = Total Deformation Curve Minus Set Curve.")

All Mixtures 1-2-4.

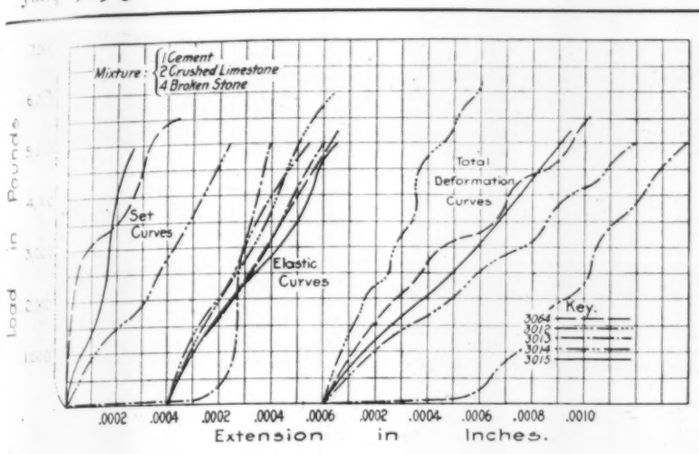
	TENSION.					COMPRESSION.			
Test No.	E at 1,000 lbs. =28 lbs. per sq. in.	E at 3,000 lbs. =83 lbs. per sq. in.	E at 5,000 lbs. =135 lbs. per sq. in.	Breaking Load lbs. per sq. in.	Test No.	E at 5,000 lbs. =135 lbs. per sq. in.	E at 25,000 lbs. =682 lbs. per sq. in.	E at 45,000 lbs. =1,227 lbs. per sq. in.	Breaking Load lbs. per sq. in.
Crushed Lime Stone and Broken Lime Stone.									
3012	5,700,000	4,670,000	5,140,000	186	3018	5,600,000	5,600,000	5,600,000	3,400
3013	5,170,000	4,085,000	4,310,000	151	3019	3,306,000	4,132,000	4,380,000	2,040
3014	6,410,000	5,130,000	4,670,000	150	3020	5,540,000	5,890,000	4,676,000	2,120
3015	5,170,000	3,610,000	4,010,000	158	3024	5,460,000	4,820,000	4,610,000	2,160
3064	4,660,000	4,050,000	4,011,000	204	3025	5,560,000	5,208,000	4,287,000	2,190
Aver.	5,022,000			170	3051	6,810,000	6,290,000	6,130,000	2,580
					3062	5,515,000	4,140,000	2,980,000	1,455
					Aver.	5,398,900			2,278
Sand and Broken Lime Stone.									
3067	4,790,000	4,790,000	4,790,000	153	3021	2,755,000	2,505,000	.....	1,500
3068	4,420,000	3,975,000	3,680,000	176	3022	4,130,000	3,940,000	3,380,000	1,920
3069	6,275,000	4,710,000	4,400,000	153	3023	2,800,000	3,650,000	3,360,000	2,000
Aver.	4,491,600			161	3026	4,100,000	3,725,000	3,210,000	1,850
					3027	2,755,000	2,666,000	2,520,000	1,760
					3058	4,190,000	4,190,000	3,350,000	1,672
					Aver.	3,687,500			1,784
Crushed Lime Stone and Broken Granite.									
3001	2,860,000	2,500,000	2,705,000	183					
3002	4,175,000	2,985,000	2,750,000	172					
Sand and Broken Granite.									
3003	2,400,000	2,160,000 at 2,590 lbs.	.....	79					

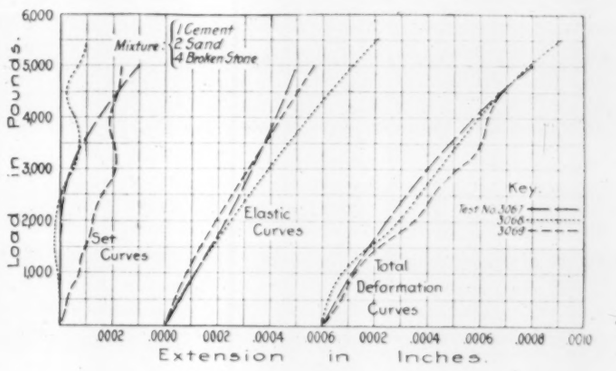
TABLE III.—Showing Moduli of Elasticity (E).

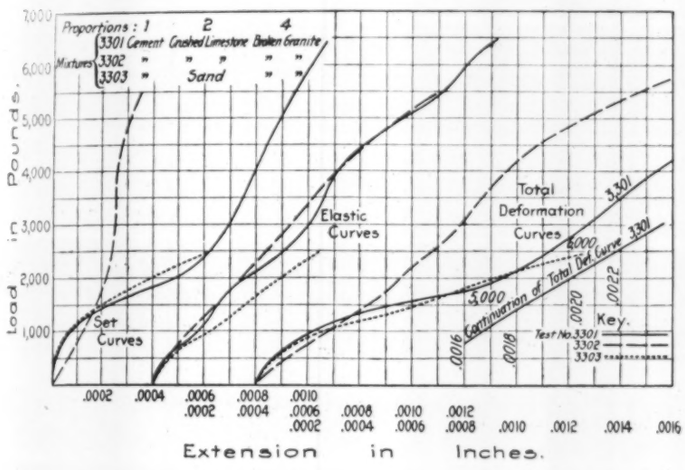
Figured from the Total Deformation Curve.

Tension			Compression		
Test No.	E	Breaking Load, lbs. per sq. in.	Test No.	E	Breaking Load, lbs. per sq. in.
Crushed Lime Stone and Broken Lime Stone.					
3012	5,700,000	186	3018	4,660,000	3400
3013	1,790,000	151	3019	3,600,000	2040
3014	2,140,000	150	3024	5,170,000	2160
3015	2,780,000	158	3025	4,460,000	2190
3064	4,400,000	204	3051	4,540,000	2580
			3062	3,180,000	1455
Aver.	3,362,000		Aver.	4,268,000	
Sand and Broken Lime Stone.					
3067	4,510,000	153	3022	2,930,000	1920
3068	2,955,000	176	3023	3,250,000	2000
3069	3,530,000	153	3026	4,230,000	1850
			3027	2,320,000	1760
			3058	3,450,000	1672
Aver.	3,665,000		Aver.	3,286,000	

NOTE.—The values of E in Table III. were all calculated at points on smooth parts of the curves where deflections seemed most regular. For tension the loads varied from 3,000 lbs. to 5,000 lbs., or about 100 lbs. per sq. in. For compression the loads ranged from 25,000 lbs. to 35,000 lbs., or about 1,000 lbs. per sq. in.







FIGS. 20—22.

DIAGRAMS SHOWING SET CURVES, ELASTIC CURVES, AND TOTAL DEFORMATION CURVES OBTAINED FROM TENSION AND COMPRESSION TESTS OF CONCRETE AT COLUMBIA UNIVERSITY LABORATORIES.

Legend.—Dotted lines indicate set curves; dot and dash lines indicate true elastic curve; full lines indicate total deformation curves.

TABLE I.—SHOWING STRENGTH OF CONCRETE IN TENSION AND COMPRESSION.

Test Number.	Breaking Load in Pounds.	Load in Pounds per Sq. Inch.	Mixed With.	Treatment: Days in Mould.	Days in Water.	Days in Air.	Remarks.
TENSION.							
Lot No. 1.							
2968	9,300	267	Crushed Lime Stone.	1	6	21	* Indicates that deformations were measured.
2969	9,950	282	" " "	1	6	21	
2970	8,370	238	" " "	1	6	17	
2971	4,360	130	" " "	3	6	24	
2972	8,860	250	" " "	2	7	26	
2973	6,990	201	" " "	2	7	26	
Lot No. 2.							
3012*	6,550	186	" " "	2	5	46	
3013*	5,250	151	" " "	2	5	43	
3014*	6,300	150	" " "	2	5	47	
3015*	5,500	158	" " "	2	5	43	
Lot No. 3.							
3063	5,370	156	" " "	1	6	20	
3064*	7,140	204	" " "	1	6	23	
3065	7,250	208	" " "	1	6	22	
3066	4,870	138	" " "	1	6	20	
Average		194					
3067*	5,250	153	Astoria Sand.	1	6	17	
3068*	6,000	176	" "	1	6	17	
3069*	5,500	153	" "	1	6	15	
3070	2,330	(65)	" "	1	6	15	Defective Specimens.
Average		161					
3301*	6,590	183	Crushed Lime Stone.	1.5	6	17.5	Mixed with broken granite instead of lime stone.
3302*	5,950	172	" " "	1.5	6	18.5	
3303*	2,620	79	Astoria Sand.	1.5	6	16.5	* 3303 defective specimen.
COMPRESSION.							
3018*	121,500	3,400	Crushed Lime Stone.	1	6	50	
3019*	74,200	2,040	" " "	1	6	50	Number—3021—Low breaking Load caused by unequal distribution of load as ends of specimen were not bedded in plaster.
3020*	76,500	2,120	" " "	1	7	71	
3024*	79,200	2,160	" " "	1	6	53	
3025*	78,800	2,190	" " "	1	6	54	
3051*	91,100	2,580	" " "	1	6	22	
3052	88,700	2,506	" " "	1	6	20	
3053	87,400	2,440	" " "	1	6	20	
3054	90,200	2,608	" " "	1	6	20	All compression specimens mixed with broken lime stone.
3059	64,300	(1,822)	" " "	1	6	14	
3060	64,500	(1,798)	" " "	1	6	15	
3061	54,900	(1,525)	" " "	1	6	15	
3062*	52,800	(1,455)	" " "	1	6	13	
Average		2,449					
3021*	54,300	1,500	Astoria Sand.	2	5	47	
3022*	69,800	1,920	" "	2	5	47	* Indicates that deformations were measured.
3023*	71,500	2,000	" "	2	5	47	
3026*	67,700	1,850	" "	2	5	49	
3027*	63,700	1,760	" "	2	5	49	
3055	60,500	1,725	" "	1	6	21	
3056	64,500	1,810	" "	1	6	21	
3057	52,300	1,441	" "	1	6	21	
3058*	59,900	1,672	" "	1	6	22	
Average		1,753					

Figures in brackets were omitted from averages because they were either defective specimens or lacked age.

value of E is frequently calculated from the total deformation curve. The writer supports the contention that this is not the true value of E; however, since such figures are prevalent, the value of E has been calculated from several of the total deformation curves for purposes of comparison. Table III. gives these results, and it will be noted that the average value for the same mixture is decidedly lower than when calculated from the true elastic curve of the same specimen.

Special attention is called to two or three peculiarities in the curves which have seriously disturbed the writer's peace of mind; since, so far as known, no corresponding phenomena are shown in the published results of other investigators. However, the work was conscientiously done with all possible care. The data are presented just as found, although not all in accord with preconceived notions. Publicity may bring forth useful criticism or explanation.

The numerous negative sets are the most conspicuous irregularity. These show in both tension and compression tests. They vary in amount from a mere trifle, as in test No. 3,019, Fig. 5, to a very decided minus deformation, as in test No. 3,020, Fig. 10. The first appearance of this peculiarity was supposed to be due to some error in reading the instrument, but the same thing repeatedly appearing when the greatest care was taken to insure accuracy, seemed to prove that the difficulty should not be attributed to careless operation. In all cases but one, the negative tendency gradually lessened as the load increased until the curve crossed back to its normal position. The exception was test No. 3,012, Fig. 12, in which the set curve ran parallel to the ordinate until the specimen failed.

The cause of this irregularity in the curves is still problematical. Perhaps a solution may be found in the suggestion that the specimens giving these results were under internal stress due to contraction in setting of the cement, and the loading released this stress and produced the negative deformation. Information from other investigators who may have noted this defect will be gladly received.

A second prominent charactistic is the occurrence of more or less regular waves in certain curves. This tendency was so persistent, it was decided to plot the curves through the points just as read, without attempting at averaging. The peculiarity is confined to the tension tests, and no satisfactory explanation has been offered. Test No. 3,012, Fig. 12, previously mentioned in con-

TABLE IV.—Showing Results of Absorption Tests on 8-in. Cubes of Concrete.

Specimen Marked.		Per cent. Absorption after Soaking. 4 hours.	24 hours.	48 hours.
20	Sand mixture	2.63%	2.63%	2.91%
21		3.07	3.22	3.66
22		2.91	3.05	3.49
14	Crushed lime stone mixture.	2.64	2.64	3.12
15		2.37	2.51	2.95
23		3.13	3.27	3.70
24		3.00	3.00	3.29
25		3.14	3.14	3.43

nection with negative set, is a good example of this character curve. To a certain extent these irregularities appear in the plotting of the true elastic curves, but the prominent features are eliminated and a fairly normal curve is obtained.

An excellent illustration of how a perfectly normal elastic curve may result from wildly erratic working curves, may be seen in tension test No. 3,013, Fig. 13. In this test the first deformation readings were so excessively exaggerated it would indicate very strongly that the instrument had slipped, or that the initial reading was incorrect, though an examination at the time gave no indication to that effect. Whatever the cause, the freakishness disappears in the resultant elastic curve and the coefficient of elasticity is with others of the same lot.

Uniformity in character and value of the elastic deformation curves, whatever their antecedents, is shown by a study of the grouped curve sheets, Figs. 18 to 22. The angle they make with the ordinates may vary with the mixture as is noted by a study of Figs. 18 and 19, which represent sand and crushed limestone mixtures in compression; the same mixtures in tension give almost identical curves as shown by Figs. 20 and 21.

As a whole, it is interesting to note how closely any one group of these elastic curves approaches an average straight line. They fall surprisingly near each other, considering the possible variations in the quality of the specimens. Though the average curve for any particular mixture is practically a straight line in both tension and compression, the two lines make different angles with the ordinate, so would not make a continuous straight line if plotted as plus and minus curves through the origin. While individual curves might seem to indicate approximately an elastic limit, the groups as a whole give no foundation for such an assumption.

As an experiment, three tension tests were made upon specimens in which the broken stone was a coarsely crystalline granite instead of limestone. Complete data of these tests are given in the tables and curve sheets. The strength was about the same as the limestone mixture of the same age, but the elongations were practically twice as much. The coefficient of elasticity was correspondingly lowered.

The concretes were also tested for absorption. The amount of water taken up was found to be surprisingly small and practically the same for both mixtures. The tests were made upon a series of 8-in. cubes which were about three weeks old. The cubes were first kiln-dried for 13 days, at about 120° F. Having dried to practically a constant weight, they were then immersed in water. The percentage of absorption was calculated by weight, and was determined at different periods of time from four hours to two days. Table IV. gives the percentage values determined from the various specimens and shows the uniformly low values obtained. These figures show that the absorption on good concrete can be kept extremely low. Common well burned clay brick will show an absorption of 12 to 15%, or even higher, in some cases.

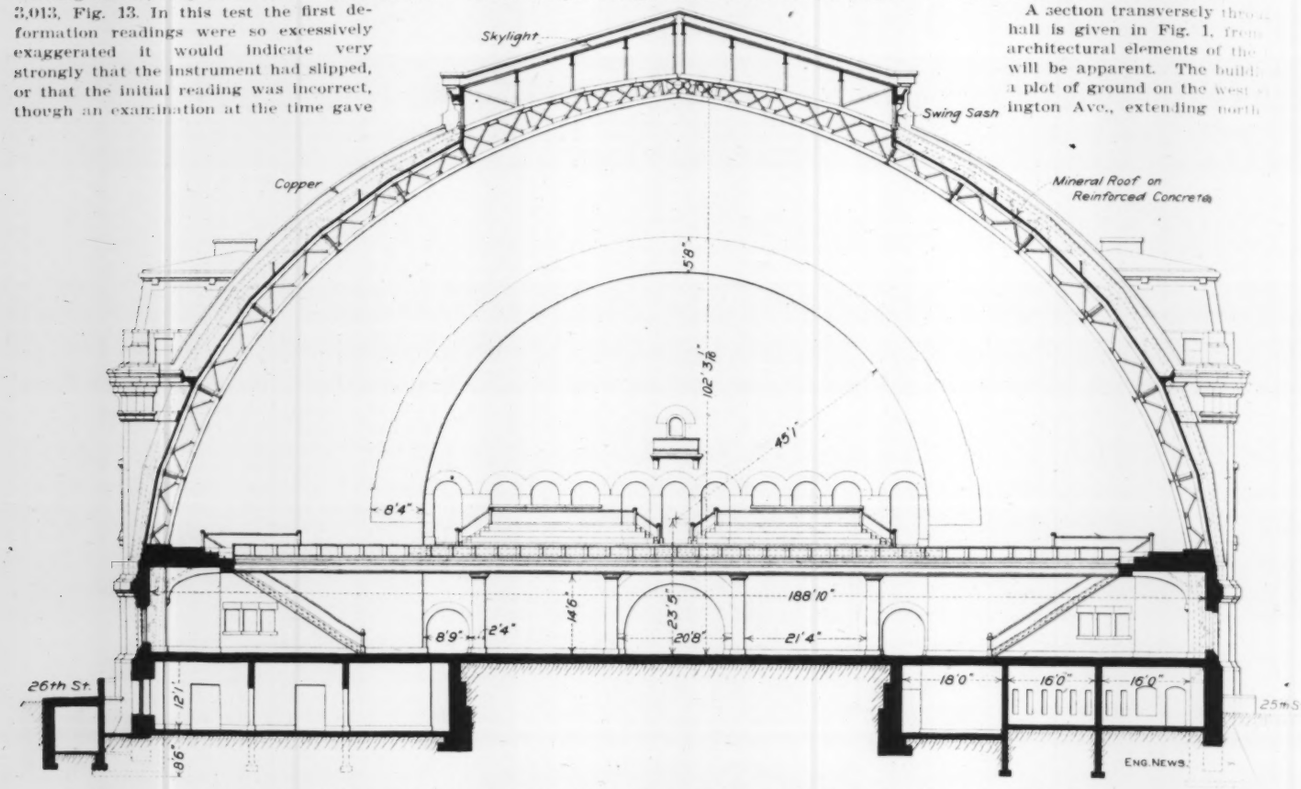


FIG. 1. CROSS SECTION THROUGH DRILL HALL, 69TH REGIMENT ARMORY, NEW YORK CITY.

THREE-HINGED ARCH ROOF OF THE NEW 69TH REGIMENT ARMORY, NEW YORK CITY.

Several new armory buildings for State militia are at present under construction in New York City, among them one for the Sixty-ninth Regiment, on Lexington Avenue, between 25th and 26th Sts., in the Borough of Manhattan. A building such as is required for armory purposes offers an interesting structural problem in the framing of the drill hall, which hall in the ordinary case is 150 to 200 ft. wide by 200 to 300 ft. long. In the earlier construction of such buildings it was common practice to span the drill hall by simple trusses, usually with a chord and straight (or nearly straight) chord. Frequently, however, [illegible] particularly in more modern practice, 69th Regiment Armory offers a good example of such an arched roof. Drawings of the roof are shown herewith.

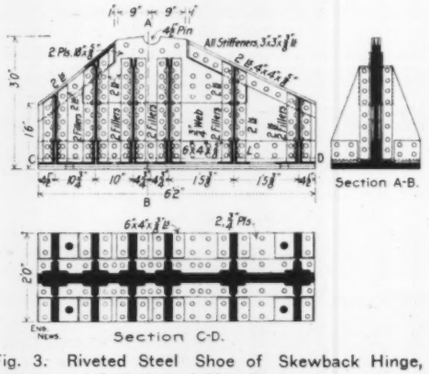


Fig. 3. Riveted Steel Shoe of Skewback Hinge, Arches of Drill Hall of 69th Regiment Armory.

A section transversely through the drill hall is given in Fig. 1, from which the architectural elements of the building will be apparent. The building occupies a plot of ground on the west side of Lexington Ave., extending north the full length of the block between 25th and 26th Sts. (200 ft.), and running back (westerly) about 250 ft. The front part of this plot, about 50 ft. in depth, is utilized for the administration building. This is a five-story structure framed in steel, in ordinary manner, with brick walls and stone facing and trim. A mansard roof with skylights covers this part of the building. The remainder of the plot, the westerly 200 ft., is occupied by the drill hall, a clear space very closely 200 ft. square covered by an arched roof. The floor of this hall, at ground level, rests on undisturbed soil in the central portion, while along either side there are three rifle-range passages beneath the floor. The roof of the drill hall is, roughly, semi-circular in form. The lower part along each side is faced by the side walls, carried up to about 25 ft. above the street level; at the truss towers the walls form heavy pilasters or piers rising to about 65 ft. above the street. The roof proper covers the remainder of the arch, except that a full-length monitor skylight 77 ft. wide occupies the middle part of the roof. On the inside the curve of the arches is broken only by a shallow balcony extending along either side and continued across the eastern gable wall. The balcony is carried by cantilever brackets on the arches, leaving the drill-hall floor quite clear of posts.

A prominent feature of the architectural development of the drill hall is the heavily ribbed effect of the roof, an effect which is produced by a special arrangement of the steel frame. The arches, which are the main members of the roof framing, are set in pairs, forming braced towers, 6 ft. 8 ins. on centers in the tower, adjacent towers being 32 ft. 1½ ins. apart in the clear (or 38 ft. 9½ ins. on centers). The roof between towers is carried on I-beam jack-rafters resting on lattice purlins. The surface of the roof is several feet *below* the top chords of the arches (in

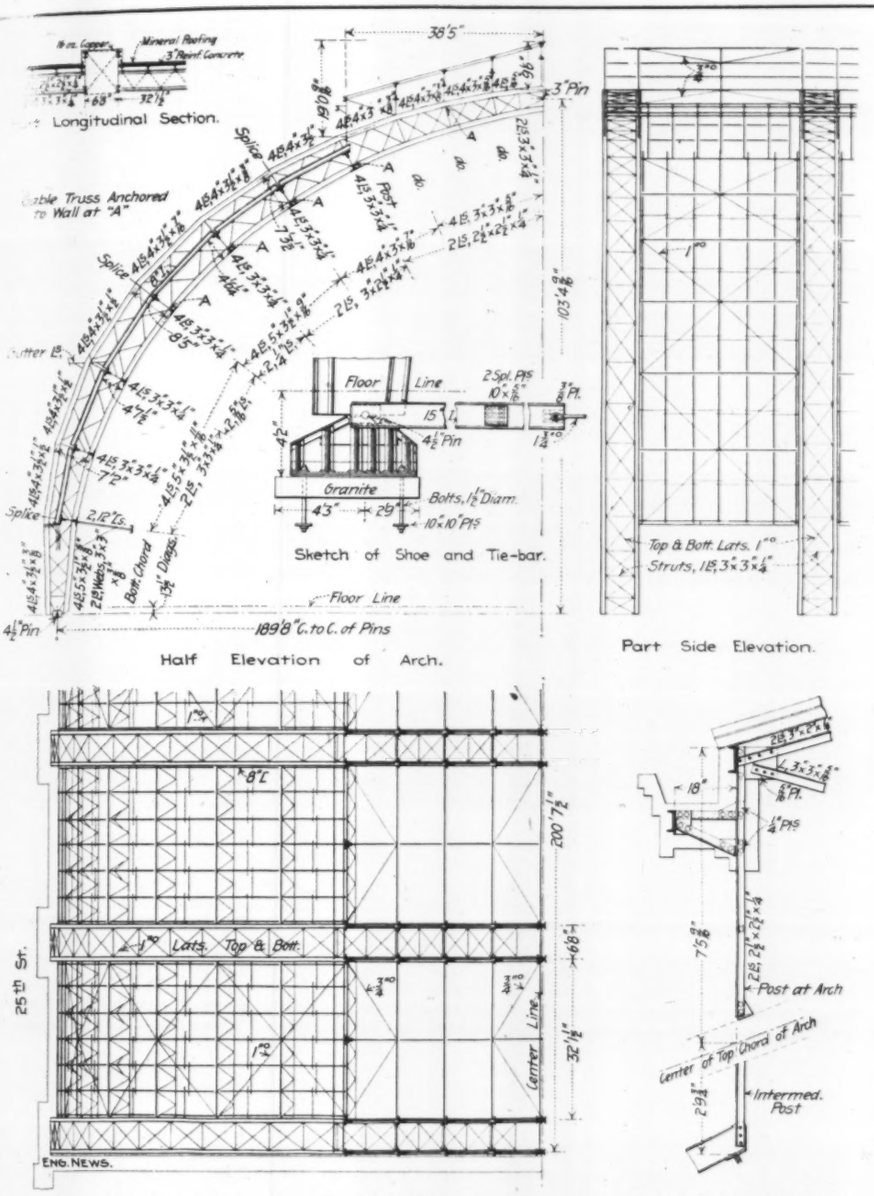


FIG. 2. STEEL FRAMEWORK OF DRILL HALL, 69TH REGIMENT ARMORY.

radial direction), which arrangement gives the roof externally a panelled appearance with the pairs of arches standing out in deep relief as heavy ribs. The surface of the ribs, that is the casing around the arch towers, is formed of 16-oz. copper. A small sketch of this arrangement is given in the upper left corner of Fig. 2.

The principal facts concerning the roof framework are brought together in the drawing Fig. 2, which shows a half section through the roof (side elevation of an arch), a part plan of the framing, a part side elevation, and some details of the construction. The leading dimensions and the sizes of the principal members are given in this drawing.

The arches are three-hinged, as already noted. To eliminate the outward thrust on the abutment piers, tie-rods are run between opposite arch shoes. These ties are just below the surface of the floor, and (except in the center portion) they lie in the ceiling of the rifle-range rooms. For better utilization of metal they are in these portions made part of the floor framing. As is shown by a detail sketch in Fig. 2, the end sections of the arch ties are 15 in. I-beams, which are also main beams of the drill hall floor over the rifle-ranges. In the center portion, between the rifle-ranges of the two sides, the tie is a single 1¾-in. round rod, connected to the 15-in. I portions by means of pin and loop-eye connection. Turnbuckles are fitted to the rod for adjustment.

The arches rest on heavy riveted steel shoes, one of which is shown in detail in Fig. 3. Since the thrust of the arch is provided for by ties, it might be expected that the shoes would be designed for vertical reactions only. However, a considerable horizontal thrust of the arches against the shoes appears to be contemplated. The shoes are unsymmetrical about the vertical plane through the end pin, having the greater base area on the outer side. The foundations are similarly constructed, being stepped out on the outer face so as to give an inclined line of resistance. This construction of foundation and shoe will permit adjusting the tie-rods to take only that part of the thrust which exceeds the capacity of the foundations.

The arches are in outline approximately semi-circular (strictly they are five-centered), as is the roof itself. Their effective depth varies, being least at the hinges and greatest at about quarter span, where it is 8 ft. 5 ins. between centers of chords. The internal design of the arches is quite simple: the chords are latticed four-angle I sections, and the web-system is a double-intersection diagonal system, with radial posts at the points where the purlins are connected. Fig. 4, a detail drawing of the base section of one arch, exhibits the style of detailing.

The two arches of a pair or tower are connected by a full top and bottom lateral system, comprising transverse struts of single angles and crossed diagonals of 1-in. round rods. These rods have simple screw and nut ends, and connect to the arches by passing through holes in short angle clips riveted to the inner faces of the gusset plates by which the struts of the lateral system connect to the arches. Some of these clips are shown in Fig. 4. The lateral bracing in the towers extends only to the panel point nearest the center pin, leaving the pin the sole connection between the halves of each arch. Sway frames of single-angle crossed diagonals are fitted between the two arches of each tower at the purlins.

Lateral bracing of the roof as a whole is provided by crossed diagonals of 1-in. round in the plane of the top flange of the purlins, running between adjacent towers, in alternate bays. This rod bracing extends upward only as far as the monitor, and is supplemented in the monitor roof by ¼-in. rod diagonals in the eave and peak panel on either side of the ridge.

The secondary roof framing comprises lattice purlins spanning the bays between towers, and 8-in. I-beam jack-rafters, running up and down the roof, resting on the top flanges of the purlins. Purlins and jack-rafters are sufficiently shown in Fig. 2 to make further description unnecessary. The space between jack-rafters is about 5 ft., and this span is covered by a reinforced-concrete slab construction. Mineral roofing laid on the concrete forms the weather surface, except that the surface over the towers is of copper as previously noted. The roof slab, put in by the Roebling Construction Co., is of that company's Type B. The concrete is 3 ins. thick, and the reinforcement consists of 1½ × ⅛-in. bars set on edge, 16 ins. apart, spanning across between jack-rafters.

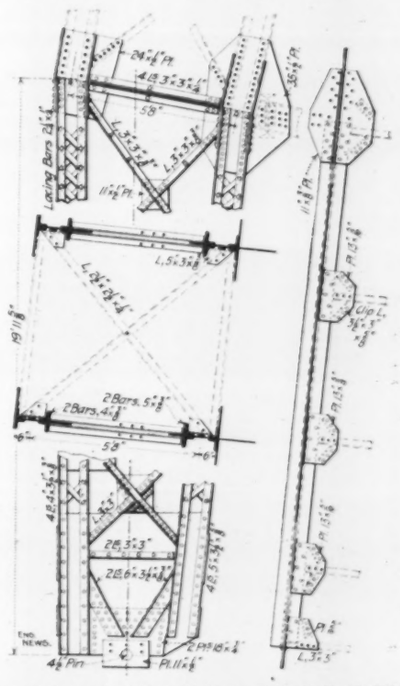


Fig. 4. Base Section of Arch, Drill Hall of 69th Regiment Armory.

Over the monitor, where the entire roof surface is occupied by skylight, the secondary framing differs from that just described as may be seen in Fig. 2. Monitor frames, set on each arch, are connected by latticed purlins, except at the eave, where a longitudinal channel takes the place of the purlin. An intermediate monitor post is pro-

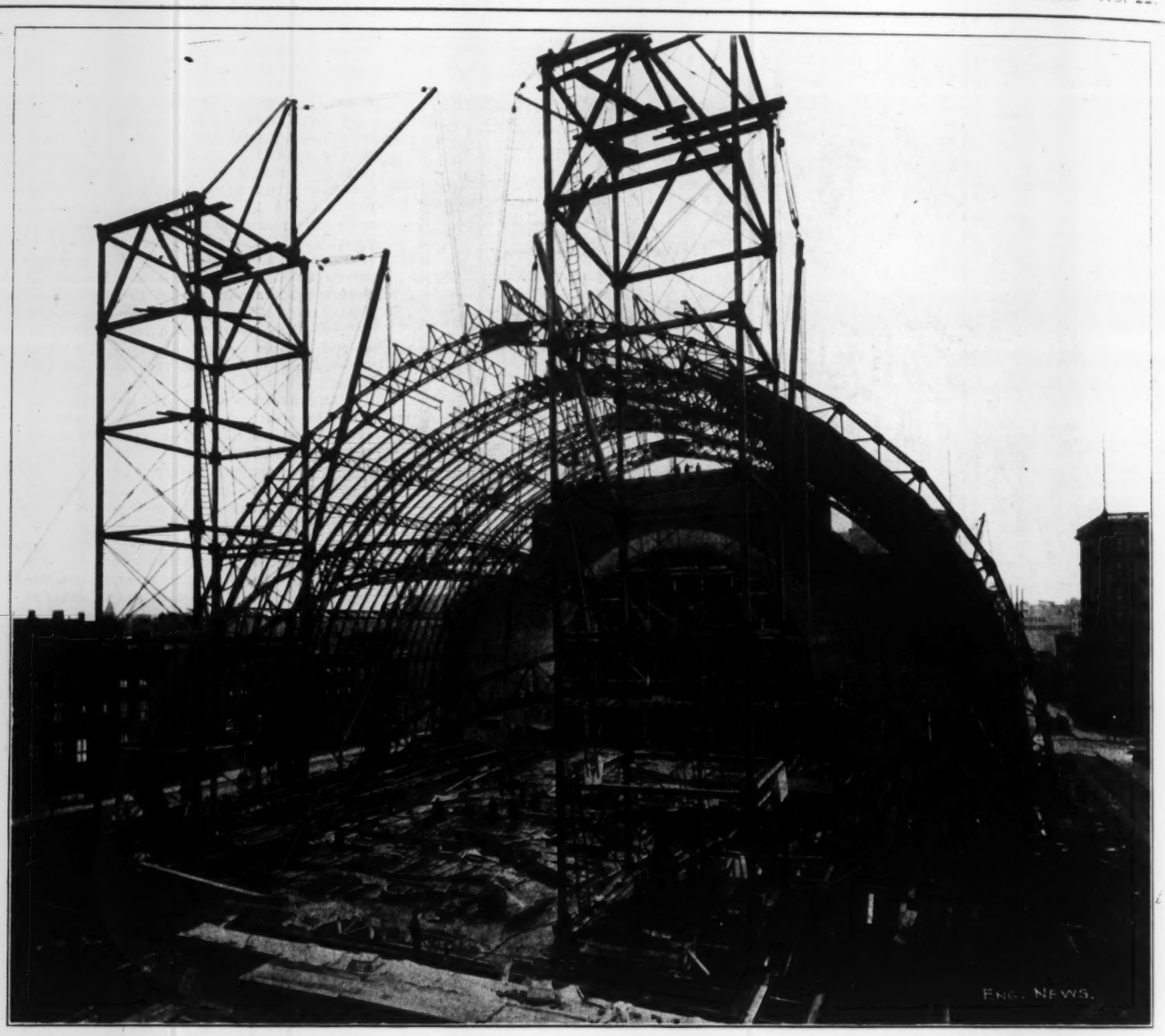


FIG. 5. VIEW OF DRILL HALL FRAMEWORK DURING ERECTION, SHOWING TRAVELING DERRICK TOWERS.

vided in the middle of this channel, footing on the upper end of a jack-rafter of the main roof. The monitor sides are further provided with light angle framing for swing sash, as indicated in the side elevation in Fig. 2. The skylight over the monitor finds its support directly on the purlins.

An interesting detail accessory to the framework of this building is the expansion anchorage which ties the gable walls to the end arches. Such anchorages are provided at ten points of each end arch, at the points marked "A" in Fig. 2. In view of the possible expansion and contraction of the steelwork with changes of temperature, which would produce a rise or fall of the arches relative to the gable walls, these anchorages were required to permit a relative vertical motion of 3 ins. above or below the normal position. The detail devised to meet this condition is shown in Fig. 7. Vertical guides are fastened firmly to the wall by hook bolts. A stud bolt is fastened by nuts to the web splice plate of the arch chord, directly opposite these guides, and bears a rectangular washer or slide block which engages the guides.

A noteworthy feature of the building, not related directly to the steel framework above described, is a large brick arch in the gable wall between drill-hall and administration building (see Fig. 1). The arch is 90 ft. 2 ins. in clear span, and is in form a complete semicircle. The ring thickness varies from 8 ft. 4 ins. at the springing to 5 ft. 8 ins. at the crown, in regular offsets of 4 ins. In axial direction the arch has the thickness of the wall which it supports, 3 ft. As the mass of wall to either side of the opening is relatively small, and the height of the opening extends down a relatively large distance below the springing line of the arch, it was thought desirable, to avoid possible cracking of the wall, to tie across the base of the two side piers by a positive tie. An I-beam tie was bonded in the foot of the wall for this purpose, at the ground floor level, extending the full length of the wall. The section of beam at either end of the tie has short vertical pieces of angle riveted to it, to interlock with the brickwork and take up any outward thrust. The tie is represented in Fig. 6, where an end-section and the splice by which the next inner section is attached are shown.

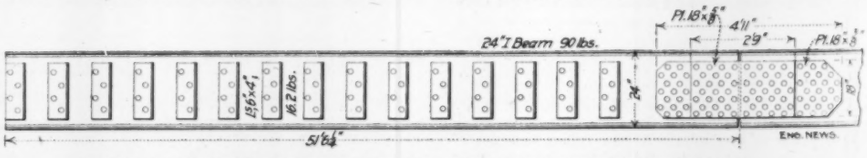


FIG. 6. TIE-BAR FOR 90-FT. BRICK ARCH, 69TH REGIMENT ARMORY.

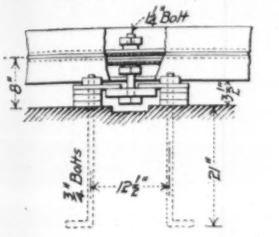
The erection of the drill-hall roof was handled by means of two traveling derrick towers in the way, illustrated by the drawing Fig. 8, and the photographic view Fig. 5. These towers are combination timber and steel structures, with bolted connections, and carry 14-ton boom derricks, one tower having two, the other three booms. One tower is placed on either side of the longitudinal center line of the building, at about quarter span, a few feet away from the arch to be erected. By means of the several booms all the parts of the arch can be hoisted and held in place until connected.

As indicated in Fig. 2 (by the word "splice" noted at the proper points of the half arch), each arch was shipped in a number of sections. Before erection the sections were assembled on the ground in complete half arches. Each tower then hoisted its half arch into place, set it on the skewback pin, and lowered it to connection at the center. By placing a few of the purlins, or temporary struts in their place, the arch was braced to the previously erected steelwork sufficiently to allow all the remaining parts to be placed at convenience.

The loadings on which the design of the drill hall roof was based are: Dead load 40 lbs. per sq. ft. of horizontal projection; snow load 30 lbs. per sq. ft. of horizontal projection; and wind

...re (horizontal) 30 lbs. per sq. ft. of vertical ...ion. The stresses used follow the provis... ...f the Building Code of New York City: ... lbs. per sq. in. in tension or bending, and ... lbs. (reduced by subtracting 58 l ÷ r) for ...n compression.

...69th Regiment Armory was built for the ...y Board of the City of New York. The



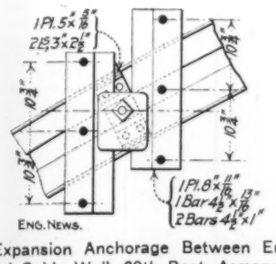


Fig. 7. Expansion Anchorage Between End Arch and Gable Wall, 69th Regt. Armory.

architects for the building were Hunt & Hunt, of 28 East 21st St., New York. The J. D. Murphy Co., of 1181 Broadway, New York, took the general contract for the construction, sub-letting various portions of the work to special contractors. Milliken Bros., 11 Broadway, New York, built and erected the steel framework, under general designs prepared by Lewinson & Co., of 128 West 42d St., New York, who acted as engineers to the architects. The erection of the steel frame of the drill hall was accomplished in six weeks' time.

ELECTRICITY ON STEAM RAILWAYS.*

By Clement F. Street, M. Am. Soc. M. E.†

At the present time the demands of heavy suburban service are beyond the capacity of the steam locomotives, and the indications are that within a few years a large proportion of this service will be handled by electric equipment. The next class of service in which it will be introduced is for the operation of pushers on heavy grades. Its extension to trunk lines will not be made in the near future, as the heavy expenditures and the engineering problems involved will retard this development, but when traffic conditions demand the change it will be made. Many branch lines which are now operated with steam locomotives can be equipped with electricity to advantage, and the competition arising from parallel electric lines will force this change at many places within the near future. The question of the advisability of making such a change is purely a financial one, as there is no doubt as to the practicability of electric traction. The engineering questions are those which relate to the specific apparatus and motors which are best for meeting particular conditions.

The feature of electric traction which is at the present time receiving the most careful consideration of steam railways is the advisability of operating their suburban lines by means of electricity. One of the changes which has taken place in this service is the elimination of a large portion of purely local traffic which has been mixed with it, and which is undesirable if it must be handled on the same tracks and with the same cars as the suburban. The electric street railways have taken over practically all of this local traffic, and with this eliminated, the suburban lines can introduce schedules and equipment designed for purely suburban traffic and handle it efficiently.

The excellent service which the electric street railways have provided has resulted in a wide extension in the area of the territory they serve and the building up of sections formerly looked upon as inaccessible for residence purposes. These extensions have resulted in a corresponding increase of the area served by suburban lines, and there is therefore a demand for a longer haul of the average suburban passenger. It is believed this demand for a longer haul has greatly enhanced the attractiveness of this class of service and makes it possible to realize a profit on lines formerly operated at a loss.

*Abstract of a paper read at the May meeting of the Western Railway Club, Chicago.

†Westinghouse Electric & Mfg. Co., Pittsburg, Pa.

The efficient handling of suburban traffic requires the operation of trains at high speeds through sections which are thickly populated, and also large and expensive terminal facilities. Exactly the same requirements exist in connection with the handling of trunk line service. Both classes required a private right of way without grade crossings, a complete system of block signals, interlocking plants and safety appliances. Many railway systems having terminals in large cities, have, within the past few years, spent large sums of money in providing these facilities by the erection of depots, abolishing grade crossings, and the introduction of the most modern safety appliances. The expenditure in connection with these improvements has been large and in order to earn a reasonable rate of interest thereon it is important that they be worked to their full capacity. The handling of through trains requires only a small proportion of the capacity of most of them and it is not believed, as a general proposition, the profits realized thereon will pay interest on the investment. These terminals are useless for the handling of freight traffic and the suburban traffic should therefore be developed and placed on a profitable basis in order to increase their earning power.

Some railroads have been making improvements in the equipment used in suburban service. The character of the cars employed has been improved, and in order to increase the speed at which trains can be operated there has been a large increase in the weight of locomotives. Even these costly improvements are not meeting the competition of electric lines, and if the full earning power of this traffic is developed the adoption of electricity as a motive power is imperative.

INCREASE IN GROSS RECEIPTS.—A better suburban service can be given with electric than with steam equipment, and all records show that the introduction of electricity is followed by a large increase in gross receipts. On one elevated railway there was an increase of 46%, and on another an increase of 68% in one year. On the Mersey Ry., in England, the change from steam to electric equipment resulted in an increase of 44% in the number of passengers carried in the corresponding six months of the year following the change. On one division of the Lancashire & Yorkshire Ry. it has been found necessary to make an increase of 62% in the number of trains in

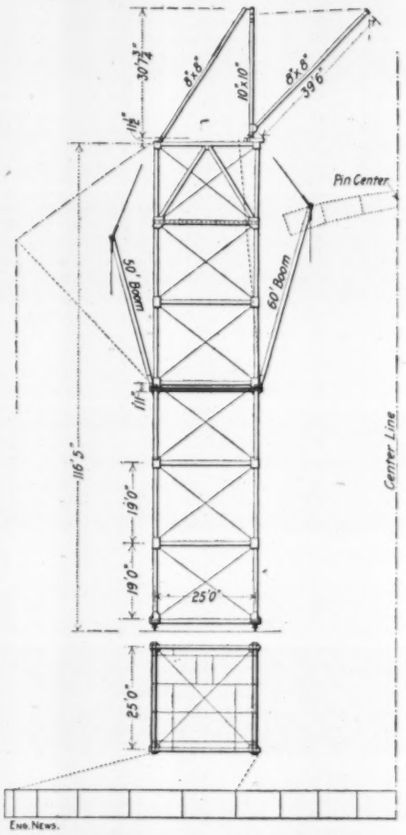


Fig. 8. Derrick Towers and Method of Erecting Arches of Drill Hall Roof, 69th Regt. Armory.

order to care for the increased traffic following a similar change. Both of these roads handle a heavy suburban traffic and the increase was almost wholly in this service.

APPLICATION OF POWER TO TRAINS.—A system of traction having power units attached to the trucks of the cars is desirable for suburban service for the following reasons: (1) A high rate of acceleration can be obtained; (2) a change in the weight of a train does not cause a corresponding change in the rate of acceleration; (3) the rate of acceleration can be changed to suit different conditions; (4) switch engines are not required; (5) drawbar strains are distributed. These are all important in the operation of suburban service. Diagram No. 1 and Table No. I. represent approximately the change which was made in the equipment used on the Manhattan Elevated Ry. when electricity was introduced. The steam locomotive formerly used on this road weighed about 24 tons and the cars about 20 tons. The electric equipment weighs about 7 tons, the motor cars about 27 tons, and the trailers 20 tons. The drawbar pull of each system is computed as 25% of the weight of the locomotive and motor cars. This rating shows a drawbar pull of 12,000 lbs. for the locomotive, which, of course, remains constant regardless of the weight of the train. The drawbar pull of one motor car is 13,500 lbs., which gives 27,000 lbs. for a 3-car train having two motor cars and 54,000 lbs. for 5, 6 and 7-car trains, each of which is run with 4 motor cars.

The cars in use on the Manhattan elevated are much lighter than those in general use for the suburban service of steam railroads. In a comparison between 100-ton locomotives hauling 35-ton cars, and 51-ton motor cars with 35-ton trailers, it will be seen that with a 9-car train the drawbar pull is 50,000 lbs. with a steam locomotive and 127,500 lbs. with electric motors. With electric equipment it is assumed that 5 motor cars will be operated with a 9-car train, but it may be found better practice to use 6 motor cars with a train of this weight, and under this condition the electric equipment will have a still greater advantage. The comparisons illustrate very forcibly the flexibility of electric equipment and the manner in which the drawbar pull can be adjusted to suit different conditions. If an unusually rapid acceleration is required, there is no reason why trains should not be operated with all motor cars; on the other hand, where rapid schedules are not essential and few stops are made, one or two motor cars can be used on a 5 or 6-car train. The total weight of train in Table I. is very nearly the same for both systems, but when heavier equipment is used the electric equipment has a considerable advantage. With 3 and 4-car trains the difference is 68 tons, with 6-car trains 52 tons, and with 6-car trains 36 tons. A large proportion of suburban service is handled in trains of from 5 to 7 cars and a considerable number of 3 and 4-car trains are operated in this class of service. In view of this fact, this saving in dead weight is important.

INCREASED CAPACITY OF PRESENT TERMINALS.—The introduction of electricity is followed by an increase in the capacity of existing terminals for handling trains. Trains handled by electricity require only one or two switching movements. The motorman merely carries his operating lever from one end of the train to the other, and the throwing of one or two switches is the only operation required for fitting the train for a run in the opposite direction. The making up of trains and hauling of them to the depot can be performed entirely by the motor cars themselves and switch engines for this work can be dispensed with. The rapid acceleration of electric trains is another feature which increases the capacity of terminals, as it enables a more rapid movement of trains than that obtained by the use of switch engines.

REDUCTION IN OPERATING EXPENSES.—The introduction of electricity on a large elevated system was followed by a reduction in the total operating expenses of from 13.2 to 9.5 cts. per car mile (28%), and an operating ratio of from 58.1 to 41.2% of the gross earnings. A portion of this saving is in the cost of power supply and conducting transportation, but the largest saving is in the cost of maintenance of equipment. It is believed that even a greater reduction can be made in the cost of operating suburban traffic on steam railways, as the conditions under which locomotives were operated on elevated railroads were more favorable than those at most large terminals. The cost of maintenance of locomotives was always very low for elevated roads and the weight of this equipment was only about one-fourth of that in use on a number of suburban lines. The elevated roads were operating under conditions which enabled them to reduce the terminal cost of caring for locomotives to lower figures than it is possible to obtain on surface lines.

REDUCTION IN TERMINAL COSTS.—For the care of locomotives at terminal points, roundhouses must be installed and maintained, with heating apparatus, facilities for supplying water for washing boilers, cleaning tubes, making light repairs, etc.; also turntables, coal and sand supply and cinder pits, with crews and equipment for removing ashes. The average cost of roundhouse operation for such plants, with an average of 2,476 locomotives handled per month, is $1.53 per locomotive. This does not include the cost of removing ashes from the cinder pits, cost of handling coal, or the cost of supplying sand and operation of the sand house, or the cost of steam heat and water. At points where bad water must be used, and at these same points during winter months when snow and ice must be removed, these costs are higher. With electric cars the terminal costs are reduced by about 60%, and the investment in buildings and equipment reduced by 80 or 90%. The handling of coal and ashes is transferred to the central power house, but owing to the better facilities installed the cost of doing the work can be reduced. The care of electric cars does not require

TABLE I.—Comparison of Drawbar Pull on Steam and Electric Equipment.

Cars per Train.	Motor Cars per Train.	Drawbar Pull per —Train.— Electric.	Steam.	—Weight, Tons.— Elec. Equip.	Steam Locos.	Weight of Train. —Tons.— Electric.	Steam.	Drawbar Pull, Lbs. per —Ton of Train.— Electric.	Steam.	Ratio of Drawbar Pull per Ton.
3	2	27,000	12,000	14	24	74	84	364.8	142.8	2.5
4	3	40,500	12,000	21	24	101	104	400.9	115.3	3.4
5	4	54,000	12,000	28	24	128	124	421.8	96.7	4.3
6	4	54,000	12,000	28	24	148	144	366.2	83.2	4.4
7	4	54,000	12,000	28	24	168	164	329.2	73.1	4.5

expensive buildings and, as a rule, they are not placed under cover when out of service. Where this practice is followed, the only building required is a small inspection house provided with pits.

There is some variation in the system of inspection in practice on electric lines. On three elevated roads the practice is to inspect the motors, all electrical equipment and trucks every three days. At the time of this inspection the motor cases are opened, the commutators and brushes carefully inspected, new brushes applied where required and light repairs made. The amount of time required for doing this work is from 30 to 45 minutes per car and it requires a force the equivalent of about one man for every ten motor cars in service. On two elevated roads the practice is to make an inspection of each car before it enters the service in the morning. After it has run about half a mile an inspector boards the car and questions the motorman regarding the operation of each portion of its equipment. Motor cars in constant service make an average of 220 miles per day and after they have run about 50,000 miles are taken into the shop and thoroughly overhauled. The cost of labor for making inspection under each system as above outlined, and also light running repairs, is from 20 to 25 cts. per motor car per day. Assuming that six-car trains can be operated by one locomotive or by three motor cars, this gives a terminal cost of about 65 cts. for electric equipment and $1.53 for locomotives.

MAINTENANCE OF EQUIPMENT.—Table No. 2 gives figures which have been compiled from the reports of 22 electric roads, four of which are elevated and the remainder surface lines. The total operating expense per car mile varies from 10.2 to 17.39 cts., and the average is 13.14 cts. per car mile. The cost of maintenance of electrical equipment per motor car per year ranges from $34.16 up to $204.34, with an average of $107.20. The wide variation is owing to the condition in which the motors are kept, and also the service in which they are employed. Where the costs are abnormally low, the probability is that a number of new motors have recently been introduced which require a small amount of repairs, or the equipment is not being kept in repair. The average cost of maintenance for electric equipment of cars per car mile is only 0.580 ct., which is only 4.33% of the total cost of operation. This cost includes the maintenance of electric heaters and electric lights, which are used on nearly all of the roads from which these records have been taken. The cost of operation of power plants per car mile varies from 1.173 to 3.830 cts., with an average of 2.277 cts. This variation is due largely to the conditions under which the different power houses are operated. The lowest costs are for plants having a number of separate units, and when these units are in use they are usually worked to their full capacity. One of the roads for which this item is high, purchases all of its power, but another one showing a low cost is following the same practice. Nearly all of the roads purchase a portion of the power used. The costs given for maintenance of equipment includes the maintenance of steam plant, electric plant, cars, electric equipment of cars and shop expenses. In the majority of cases the two largest items which go to make up this cost are the maintenance of the cars and the maintenance of the electric equipment of cars. The cost of maintenance of the steam plant and the electric plant is so low as to be of very little importance. The general manager of one of the roads states that the total cost of repairs to three generators of 1,500 KW. and three of 800 KW. capacity during the year 1904 was less than $700.

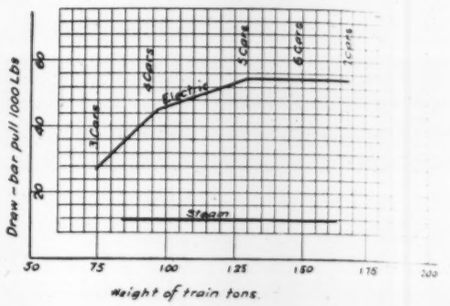
The cost of repairs and renewals of cars and locomotives on a number of steam railways averages $729 per car per year and $2,213 per locomotive per year. The introduction of heavy locomotives during the past few years has increased this cost to figures which are somewhat startling. The records of some roads for the year 1904 give the cost of repairs and renewals per locomotive per year at from $3,500 to $3,700.

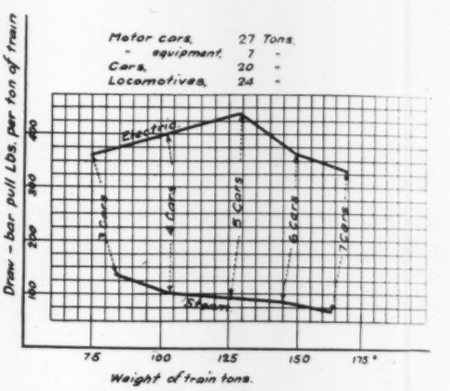
The records show that only 2½ to 3% of the trucks of electric cars are out of service for heavy repairs, but this is not the controlling feature of the availability of the equipment for service, as from 5 to 6% of the car bodies are usually out of service for painting and varnishing. The practice is, therefore, to have 2 or 3% more car bodies than trucks, and when a body is taken to the shop for painting and varnishing, the trucks (if not in need of heavy repairs) are kept in service under another body. The trucks are all interchangeable, so that in case one of them needs repairs, it can be replaced by another and the car retained in service. The time required in well equipped shops for removing a truck and putting another one in its place is from 30 to 45 minutes. This makes an extremely flexible system and one under which a large percentage of the equipment can be kept in continual service. The parts of electric equipment which wear out and require renewal are so few in comparison with those on a locomotive that neglect in keeping up repairs does not result in a corresponding deterioration in its condition.

The records of maintenance of overhead electric line per mile per year shows an average of $149 for 18 different roads. Some of these are operating a portion of their cars through suburban districts, and all of them operate through large cities where they must contend with a complication of telephone and telegraph wires, also crossings and curves which necessitate a complication of guy wires. The cost of maintaining an electric line on a private right of way is lower than the average here given. For heavy service catenary cables are used for suspending the trolley wire, which further decreases this cost. The cost of maintaining an underground conductor is $960 per mile per year, and owing to this high figure it is not included in the cost of maintaining overhead conductors. The percentage of earnings required for operating electric lines is lower than that required for steam railroads.

RELIABILITY OF SERVICE.—The records of a large elevated railway show only one-third as many delays to service owing to failure of equipment since electricity was adopted as there were when operating with steam. These records refer to actual number of delays and do not take into consideration an increase of more than 20% in the number of trains operated. Some of the officials of this road state that this is the most important benefit which that company has derived from the adoption of electricity. This reliability of service is of even more importance to steam railroads than to the elevated, where suburban service is operated on the same through trunk line trains, as any delay to one service is not only a cause of annoyance and loss itself, but is also the cause of annoyance and loss in connection with the through service.

It has been said as an argument against [illegible] ment that a failure at the power house will tie up entire service, while if a locomotive fails it does not any effect on other locomotives operating on other of the line. This is true, but the above record clusive evidence of the fact that a central power gives a more reliable service than can be obtained use of steam locomotives. One of the causes for





Diagrams Showing Traction Required on Manhattan Elevated Trains with Steam and with Electric Motive Power.

duction in the number of failures of equipment is undoubtedly owing to the even distribution of drawbar strains with electrical equipment.

COAL CONSUMPTION.—Mr. L. B. Stillwell, in a discussion before the International Engineering Congress at the World's Fair in St. Louis, made the following statement:

The saving in coal with a central station electric power plant over steam locomotives is greater than is often assumed. The plant of the Manhattan Elevated delivers power to the switchboard at the rate of 2.6 lbs. of coal per kilowatt hour under conditions of full load, and the power is delivered to the motors through the third rail with about 60% efficiency, giving a consumption of 4.3 lbs. per kilowatt or 3 lbs. per horse-power at the drawbar. A road with heavy traffic and a large and efficient central power station should use only about half as much coal as when using steam locomotives, and this may even be reduced under favorable conditions to one-third.

SYSTEMS OF ELECTRIC TRACTION.—The direct-current system was the first to be introduced and consisted essentially of a central station generating current at about 500 volts and feeding it to trolley wires, from which it was carried at the same voltage to motors on the car trucks. The limit of this system was soon reached, as it is impossible to economically transmit current at such low voltage through the distances required, and also impossible to produce a direct current at a much higher voltage. Consequently the alternating current (which seems to be unlimited as to voltage) was introduced into the system and all medium and large sized so-called direct-current roads are now operated about as follows: The central power station produces alternating current at high voltage, transmission lines feed this current to rotary transformers distributed along the line where it is transformed to direct current at from 500 to 650 volts and fed to the trolley wires, from which it is carried to the motors.

There are two objections to this system: (1) The limitation of trolley voltage; (2) the rotary converter. The maximum capacity of a trolley line of 0000 copper carrying 600 volts, is about reached in operating some of the heavy interurban cars now in use. Trains such as are used on elevated railways and in suburban service cannot be operated with this equipment, and for handling such trains either a higher trolley voltage or a larger conductor must be used. A higher trolley voltage is ma-

TABLE II.—Maintenance and Operating Cost of Electric Railways.

Road	Motor Cars.	Other Than Motor Cars.	Total Cars.	Car Miles Per Year.	Maint. Steam Plt'nt Elec. Plant and Cars per Car per Year.	Maint. of Electric Equip. of Cars per Motor Car per Year.	Total Operating Expense. Cents per Car Mile.	Operation of Cars. Cents per Car Mile.	Operation of Power Plant. Cents per Car Mile.	Maint. of Equip. Cents per Car Mile.	Maint. Elec. Equip. of Cars. Cents per Car Mile.	Maint. Electric Line per Mile per Year.
A	2,419	641	3,060	45,303,500	$217.94	$ 98.42	15.60	7.518	1.199	1.470	.525	†$960.39
B	.....	.....	3,280	47,476,702	.....	.....	17.39	.....	*2.695	1.702	.596	409.98
C	.....	.....	1,161	14,688,216	.....	.....	15.82	.....	*2.982	1.408	.762	89.42
D	548	0	548	6,849,201	185.66	85.83	11.98	5.804	2 039	1.485	.686	122.72
E	505	127	632	13,524,971	239.58	107.03	11.99	6.165	1.802	1.015	.370	102.63
F	486	2	488	6,296,662	209.96	87.47	16.00	6.333	3 830	1.646	.684	266.25
G	430	51	481	7,350,169	262.94	113.64	12 95	5.668	1.994	1.720	.664	152.86
H	394	0	394	7,627,000	277.62	135.27	13.32	7.534	1.173	1.434	.698	231.63
I	307	56	363	5,165,238	206.75	91.95	15.85	7.115	3.039	1.453	.546	135.01
J	324	73	397	5,590,145	264.12	127 31	15 10	6.352	2.910	1.875	.737	134.03
K	300	0	300	3,334,435	205.17	82.02	13.02	6.606	1.868	1.846	.738	182.00
L	251	0	251	2,449,839	92.02	34.16	11.23	5.873	1.792	.934	.349	44.47
M	232	41	273	4,334,160	270.42	89.90	13.10	5.726	2.430	1.699	.481	142.10
N	231	42	273	4,338,578	297.08	127.44	14.77	7.009	2.821	1.846	.678	144.01
O	226	5	231	5,193,023	392.94	128 83	12.38	5.891	1.644	1.728	.560	135.74
P	220	51	271	5,829,584	335.99	204.34	11.88	5.762	2 180	1.561	.662	112.68
Q	217	12	229	3,207,323	178.76	45.94	11.34	4.825	2.131	1.276	.310	111.15
R	200	34	234	8,179,769	.....	.....	10.30	3.452	1.298	1.502	.....	.....
S	137	19	156	3,012,009	296.62	94.68	12.23	4.987	2.780	1.396	.430	75.42
T	124	34	158	3,770,292	385.00	168.50	11.19	4.927	1.701	1.613	.554	91.88
U	88	271	359	10,953,668	.....	.....	11.40	.....	.....	1.483	.....	.....
V	45	124	169	4,549,920	.....	.....	10.20	4.432	3.512	.802	.....	.....
AV					$254.03	$107.20	(Cts.) 13.14		(Cts.) 2.277	(Cts.) 1.495	(Cts.) .580	$149.11

*Includes maintenance. †Underground conductor.

easily the most desirable, but as this cannot be secured with the direct-current system, the only alternative with that system is a larger conductor. Trains of this size demand a conductor of dimensions which would be prohibitive in cost if of copper, and therefore the third-rail conductor has been installed. The objections to the rotary converter are the cost of its installation and the fact that as it has moving parts it must have constant attendance. With low voltage in the trolley wire converters must be located at frequent intervals on all large systems. The installation of transformer houses is an important item of first cost, and their attendance an important item of operation.

The limitations of voltage of direct current and the cost of installing and operating rotary converters have led engineers to develop a system of electric traction which can be operated by an alternating current in the motors. The result is that in Europe a number of systems have been installed with polyphase induction motors on the cars. American engineers have refused to adopt this type of motor, as they do not consider it suitable for this service. The objections to it are that it is inherently a constant speed motor, is not economical when working at less than its full capacity and its use requires at least two overhead conductors. Instead of trying to adapt this device to traction conditions, American engineers have been devoting their energies to the development of an alternating current motor which should have all the good characteristics of the direct-current motor without its limitations. A number of different schemes have been proposed and experimented with but the only one as yet placed in actual operation is the single phase series wound commutator type alternating-current motor invented by Mr. B. G. Lamme, Chief Engineer of the Westinghouse Electric & Mfg. Co. This motor and the single phase system of operation were fully developed in 1901, and three lines are now in regular and successful operation.

With this system an overhead conductor is used and the voltage can be varied to suit conditions and requirements. The motors will operate equally well with either alternating or direct current. A section of the proposed Cincinnati & Indianapolis Ry. is being operated with a 3,300-volt alternating current through interurban sections, a 350-volt alternating current through small towns, and a 550-volt direct current through cities where existing street railway lines must be used. The current is generated at 2,200 volts in the power house and by means of static transformers having no moving parts, transformed to 33,000 volts. At this voltage it is transmitted to transformer stations located every 10 or 12 miles along the line, where it is reduced to 3,300 volts and fed to the trolley. The transformer stations require no attendants, as the feeder lines are all controlled from the power house and the stations have no apparatus with moving parts. The 3,300-volt trolley current is carried into the car by a bow trolley and through a static transformer reduced to 250 volts, for which the motors are designed. This is an extremely flexible system. By making changes in the transformers, which are not expensive, the transmission voltage, or the trolley voltage, can at any time be changed to meet the requirements of new conditions which may arise. The trolley voltage can be increased to 6,600 volts, which will give sufficient power for operating 100-ton locomotives with the same size trolley wire as now in use.

The direct-current system cannot meet all the demands of heavy trunk line railway service. It should not therefore be installed on suburban lines, as any system introduced for this service should be one which can be extended to meet the requirements of all classes of service. This system, in addition to placing a limit on the voltage, requires the use of a third-rail conductor for heavy service. This type of conductor has its place. It is giving excellent satisfaction on elevated railways, and on some lines conditions exist which will not permit of the use of any other type. The overhead conductor is in successful operation on thousands of miles of railway. The structure for supporting this type of conductor can be varied to suit conditions. In cities, iron poles are used, placed near together and the structure takes a permanent character. These answer well for low voltages, but will not do for 3,300 or 6,600, and therefore the catenary suspension cable has been introduced. It can be supported by wooden poles or by steel bridges spanning the tracks.

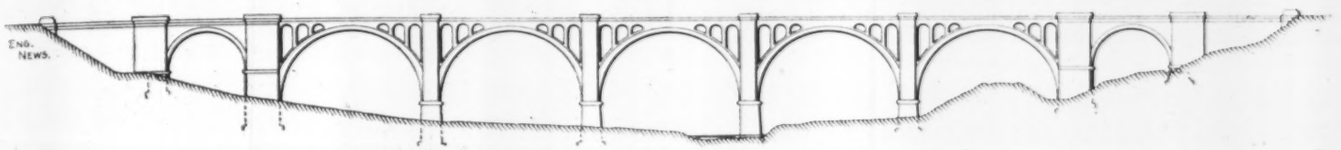


FIG. 1. DIAGRAM ELEVATION OF CONNECTICUT AVENUE BRIDGE OVER ROCK CREEK, WASHINGTON, D. C.

THE CONNECTICUT AVENUE CONCRETE ARCH BRIDGE AT WASHINGTON, D. C.

DESCRIPTION OF STRUCTURE.

The Connecticut Avenue Bridge now in process of construction at Washington, D. C., is notable in two particulars; it is one of the largest masonry arch bridges ever constructed, and it is being built of a combination of molded concrete block and monolithic concrete masonry which is exceedingly rare. As some of our readers will recall, the bridge was designed by the late George S. Morison, M. Am. Soc. C. E., whose plan was one of five plans submitted in competition to the Commissioners of the District of Columbia in 1897. Mr. Morison's plan, as submitted and as awarded the first prize in the competition, called for nine full centered masonry arches, five 150-ft. arches at the center and two 82-ft. arches at each end. In working out the final plans, this original design was modified by omitting one 82-ft. arch at each end and by changing a number of the architectural details.

CONDITIONS GOVERNING DESIGN.—The purpose of the new bridge was to provide for street traffic including street railways, and it was located where the extension of Connecticut Ave. into the National Park crosses Rock Creek. Connecticut Ave. extends from near the Executive Mansion to the limits of the District, a distance of about five miles, and is 130 ft. wide between building lines. Bordering the portion of the avenue within the city are some of the finest residences in Washington, while between the city limits and Rock Creek, where the new bridge was located, the improvements are of the best suburban type. Beyond Rock Creek to the District limits the development is all in the line of the same high class of suburban residences. The site of the bridge being conspicuous topographically as indicated, great effort was warranted to have it comport in proportions, type and style, with the dignity of the thoroughfare of which it was a part. It was for this reason that competitive plans were secured and that the massive full centered masonry arch design submitted by Mr. Morison was adopted instead of the lighter reinforced concrete and steel arches of the other competitors.

So much for the aesthetic conditions. Structurally the governing conditions were the location of the roadway at an elevation of 150 ft. above the bottom of the gorge and the placing of the piers so as to provide for three drives and Rock Creek, all crossing the line of the bridge. Provision was necessary also for a 35-ft. roadway and two 8-ft. sidewalks, for two conduit electric railways and for water and gas mains and electric conduits. The manner in which the design meets these conditions will appear in the following description.

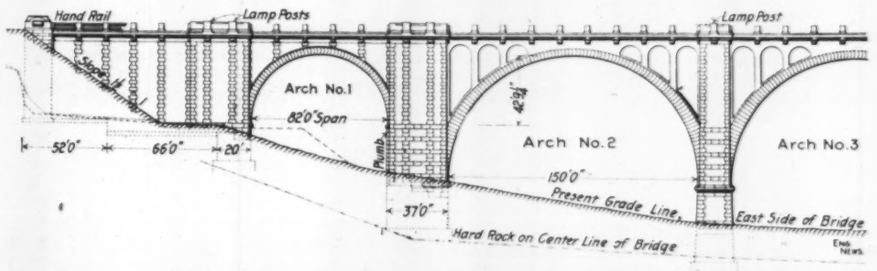


FIG. 2. PART ELEVATION OF CONNECTICUT AVENUE BRIDGE SHOWING ARCHITECTURAL TREATMENT.

GENERAL DESCRIPTION.—A diagram elevation of the bridge is shown by Fig. 1. The structure consists of seven full centered arches carried by two abutments and six piers. The two end arches have spans of 82 ft. and the five intermediate arches have spans of 150 ft. Piers 37 ft. thick separate the end arches from the wider intermediate arches and the intermediate arches are separated from each other by piers 20 ft. thick. The total length of the bridge, including abutments is, therefore, 1,341 ft.; its width between faces of arch rings is 52 ft. The 150-ft. arches support open transverse spandrel arches. The 82-ft arches support transverse spandrel arches which are closed by face walls, so that they appear as having solid spandrel walls. The entire structure, including abutments and piers, main arches and spandrel arches and roadway, is of monolithic concrete with the main structural parts outlined by molded concrete facing blocks, as shown by Fig. 2.

ABUTMENTS AND PIERS.—The seven circular arches are supported by two abutments and six piers as indicated by Figs. 1 and 2. The foundations of these structures were carried to depths of from 15 to 40 ft. to hard rotten rock with the exception of one portion of the south abutment pier or pier VI., which was founded on a softer grade of rotten rock.

Referring to the abutments first, it will be seen from Figs. 3 and 4 that they are hollow U-shaped abutments with walls having vertical faces and stepped backs. The backs of the walls are waterproofed with two coats of coal-tar pitch of the grade known as paving cement. Aside from the waterproofing the only structural detail at all unusual is the expansion joint construction adopted for the side walls.

These walls are about 135 ft. long and each has two vertical expansion joints reaching from the foundation to the floor level of the bridge. These joints are located and constructed as shown by Figs. 3 and 5. A vertical form was constructed at right angles to the wall and with planks toe-nailed to it to form the mortises for the key and the clay puddle. The view, Fig. 5, shows the end of the completed wall with the two grooves or mortises. It will be noticed that the key groove does not extend to the top of the wall, which, being but 4 ft. thick, was considered too thin to permit safely of its use. Instead of a mortise and tenon joint, this top wall section has a plain butt joint with steel rods extending across it as shown by the view, to hold the abutting walls together. The puddle groove or mortise reaches, however, from top to bottom of the wall.

The abutting length of wall is built directly against the face shown by Fig. 3, the concrete being allowed to fill the key groove so as to form a tenon in a mortise, but not being allowed to fill the puddle groove which is protected by an iron template which also fashions a similar opposite groove in the new work. The hole left by the two opposite mortises is filled with clay puddle and the joint in plan appears as shown by Fig. 3. The object of the clay puddle is to prevent seepage of water through the expansion joint. These expansion joints worked perfectly in the abutment completed last fall; in the coldest days of winter they opened about 3-16 in., and at present they have closed to 1-16 in.

The pier construction is made quite clear by the drawings of Figs. 2, 6 and 7. They are solid con-

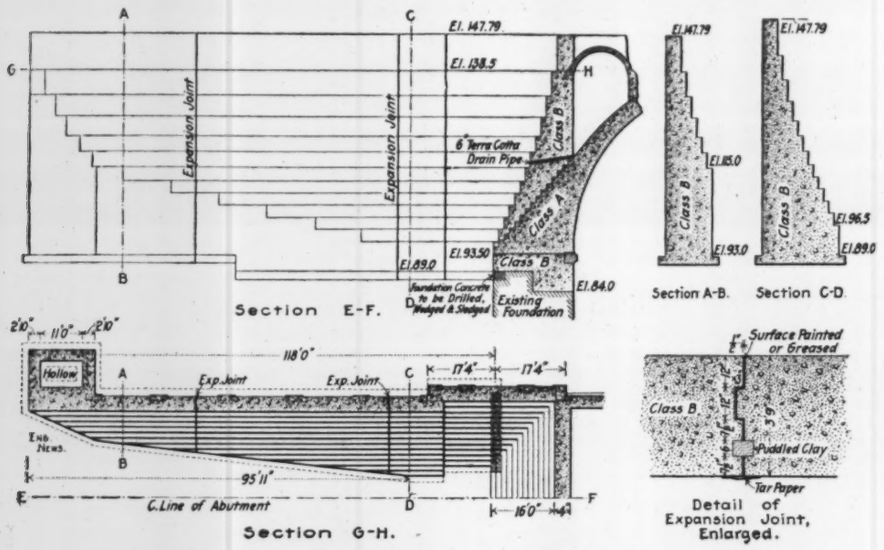


FIG. 3. DETAILS OF U-ABUTMENTS FOR CONNECTICUT AVENUE BRIDGE.

crete structures to the springing line levels of the arches and of cellular construction from there to the top which is covered by an arch, as shown by Fig. 7. Exteriorly the pier appears to extend to the top of the bridge, as shown by Fig. 2.

MAIN ARCHES.—There are seven arch spans, two of 82-ft. span and five of 150-ft. span. The rings of these arches are monolithic concrete with faces of voussoir shaped molded concrete blocks. For the 82-ft. arches the crown thickness of the ring is 3 ft. 3 ins., and for the 150-ft. arches it is 5 ft. The construction in detail is shown by Fig. 7. There is no reinforcement.

SPANDRELS AND ROADWAY.—The spandrels of the main arches are composed of relieving or spandrel arches the tops of which carry the roadway. Over the 82-ft. spans, as shown by Fig. 2, a solid spandrel curtain wall incloses the arches and gives the aspect of solid spandrel construction. The arches over the piers are also similarly inclosed, but those over the haunches of the spans are open. These relieving arches are designed with a vertical expansion joint at the crown of each. It is the intention to make these merely constructional joints and to fill them with lime mortar to act as a cushion. Since these crown expansion joints will, if they open much, convert the opposite halves of the arches into cantilevers, the rings will be reinforced. As will be seen from Figs. 7 and 8, the roadway is provided by a solid fill over the spandrel arches.

Fig. 4. View Showing Interior of U-Abutment for Connecticut Avenue Bridge.

METHODS OF CONSTRUCTION.

The work of constructing the foundations of the Connecticut Ave. bridge was executed under three separate contracts between 1899 and 1901. In the spring of 1904, the District Construction Co. began work on the structure above the foundations and has continued construction since that time. So far about $140,000 worth of work has been done; the total cost of the structure being about $800,000. Mr. Ottomar Stange is the Superintendent of Construction for the contractor. The engineers in charge of the work are: Colonel John Biddle and Captain Jay J. Morrow, Engineer Corps, U. S. A., Mr. W. J. Douglas, Engineer of Bridges, District of Columbia, and Mr. F. A. Perley, Assistant Engineer. Mr. E. P. Casey is Consulting Architect. It is expected to have the bridge completed by July 1, 1907.

CONCRETE MANUFACTURE.—About 50,000 cu. yds. of concrete will be required for the construction of the bridge. The stone for this concrete is a diorite obtained from a quarry opened in the side of the bluff about 500 ft. from the south end of the bridge. The stone from the quarry is hoisted about 50 ft. vertically by derricks and dumped into cars which travel on an incline about 250 ft. to a No. 4 Gates gyratory stone crusher into which they dump automatically. From the crusher the stone drops into a 600 cu. yd. bin under the bottom of which and beneath the ground is a tunnel large enough for a dump car. This car is handled by cable to the storage bins of a Haines gravity concrete mixer. The sand is brought to the work in wagons and dumped in a pile on a platform about 50 ft. above the bottom level of the broken stone bin. A tunnel similar to that for the stone bin and about 40 ft. from the stone car tunnel is provided for the sand car which is hauled to the mixer by the same cable that hauls the stone car, the cable being shifted by hand as desired. Cement is delivered to the mixer by means of a bag chute from the top of the gorge adjacent to the mixer.

The Haines mixer has four drops and is provided with four measuring hoppers at the top. These are filled with sand and stone from the storage bins and the cement and water are added by bags and buckets. The concrete is made quite wet so that it requires very little ramming in the forms. Both the sand and water are varied according to the wetness of the stone and the percentage of dust. This regulation is left to the head mixer and is overseen by an inspector. After passing the mixer the concrete drops into a skip or bucket mounted on a car which runs on a trestle erected the full length of the bridge and parallel to it, as shown by Fig. 9. Derricks mounted on the centering and on the cast block molding platform lift the buckets from the cars and empty them at the points where work is in progress. Each car has room for three 2-cu. yd.

Fig. 5. View of End of Section of Abutment Side Wall Showing Expansion Joint.

buckets but carries only two so that the derricks can deposit an empty bucket in the vacant space and take a filled bucket with the least waste motion. The concrete is utilized both for concrete block manufacture and for concrete deposited in place.

CONCRETE BLOCK MANUFACTURE.—As stated in a previous paragraph, all of the trimmings on the bridge below the bottom of the coping, that, is, the belt courses, quoin stones, chain stones, ring stones, brackets and dentils, are concrete blocks separately molded and set in place like cut stone. The molding or casting of these blocks is done on the ground and is one of the most important items of the concrete work. The blocks are made of concrete faced on the exposed sides with mortar composed of one part Dragon Portland cement and three parts bluestone screenings from ⅜-in. size to dust.

The method of making these blocks is as follows: Forms of ⅞-in. tongued and grooved North Carolina pine, held together by iron tie rods, are used. These boxes or molds have collapsible sides and from 6 to 8 bottoms so that the block may be left standing on the bottom for two or three weeks while the sides can be removed in as many

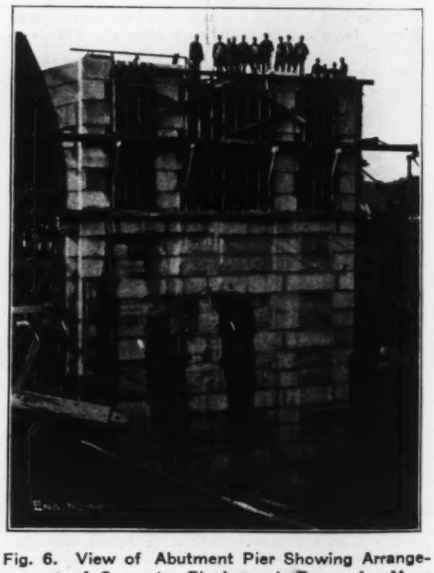


Fig. 6. View of Abutment Pier Showing Arrangement of Concrete Blocks and Forms for Mass Concrete.

days and raised with another bottom. The molding is done on a level floor of tongued and grooved boards laid on mud sills. It is noted by the engineers that the molding platform should be perfectly level to insure a uniform casting.

All blocks are molded with the principal showing face down, and if the block has more than one showing face the others are made against the vertical sides. No block is ever cast face up on account of the tendency of the cement to flush to the surface, making an unnecessarily rich mixture which was found to invariably cause hair cracks. The mode of procedure in detail is to place first the mortar facing and then deposit and tamp the backing of concrete. Great care must be exercised in this work to keep the edges full and to force the concrete stones in the backing well out into the facing mortar so as to give as much strength as possible to the edges. Before a block is cast the inside of the form is carefully cleaned and smeared with linseed oil. The blocks immediately after casting are covered with bags or old carpet and kept thoroughly wet by sprinkling. After hardening about three weeks, the blocks are removed from the bottoms of the mold and placed in the storage yard to season.

The view, Fig. 10, shows the molding platform first used; this platform was removed last spring and enlarged to cover an area of about 100 ft. square. The construction of the forms is quite clearly shown. It will be noticed that the backs of the blocks have holes gouged out while the concrete was yet soft. The purpose of these holes is to give the stone a good bond with the concrete backing. In recent work these holes have been formed by pressing blocks of wood into the soft concrete and removing them after the concrete had set about twelve hours. After the blocks have hardened from 30 to 60 days, they are bush hammered on the showing faces; the ornamental stone are bush hammered by hand and the square blocks by pneumatic hammers. It has been found that the "baby surfacer" is the most satisfactory tool for the work. There is practically no difference in the appearance of the block dressed by hand and by machines, but the machine work is considerably more economical.

The view, Fig. 11, shows some of the finished blocks. The method of marking the blocks deserves notice. As will be seen, one of them is marked Q-68, showing its place in the bridge, and underneath this mark is the date the block was molded. A complete record is kept of all blocks so that they may not be placed in the work until they are thoroughly seasoned and until opportunity for the formation of hair cracks has passed. The making of dog holes in the blocks is performed by picks when the blocks are three or four weeks old. When it is not practicable to use dogs, two-pin lewises are used. The lewises must be somewhat larger than for granite and care must be taken to decrease the pressure on the interior edge of the concrete at the top of the hole. The view, Fig. 11, also shows two ornamental blocks marked A and B. The block marked A was the original design and on account of the thinness of the top flange or member, nearly all cracked along the line shown. The projection of this flange was 1¾ ins., and its thickness 2½ ins. To remedy this trouble the form of the block was changed to that shown at B in which the thickness of the flange is 5 ins.

CONCRETE WORK IN PLACE.—All parts of the bridge, except the cast block trim, are made of concrete deposited in place in suitable forms.

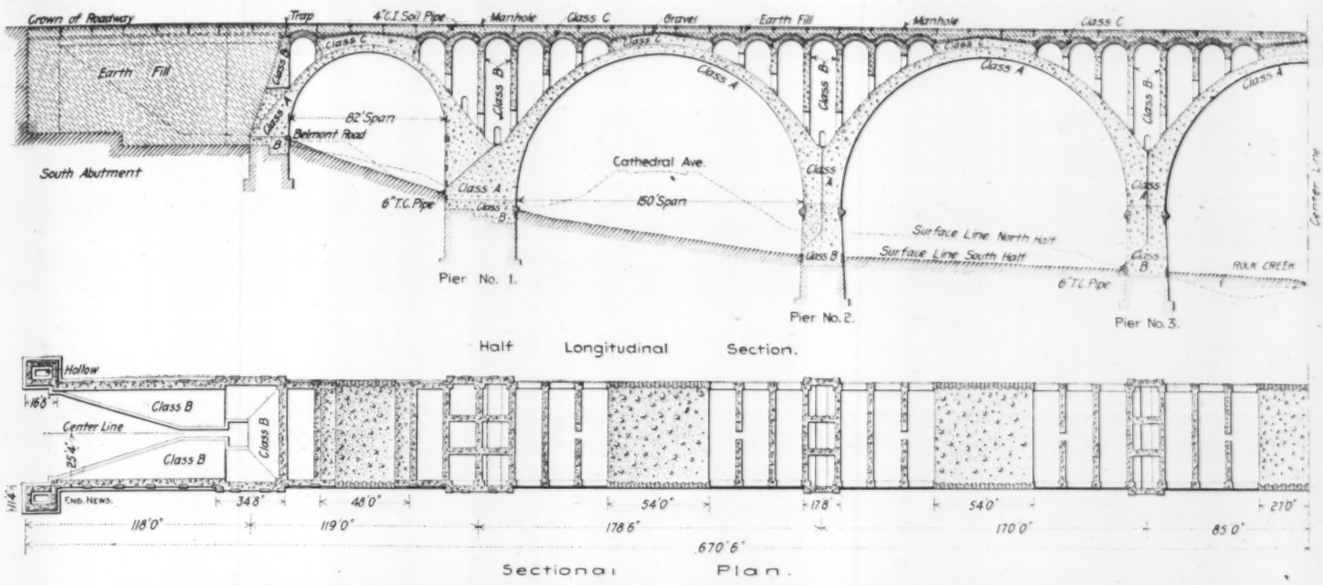


FIG. 7. PART LONGITUDINAL SECTION OF CONNECTICUT AVENUE BRIDGE, SHOWING MAIN STRUCTURAL DETAILS.

CONCRETE WORK IN PLACE.—All parts of the bridge, except the cast block trim, are made of concrete deposited in place in suitable forms.

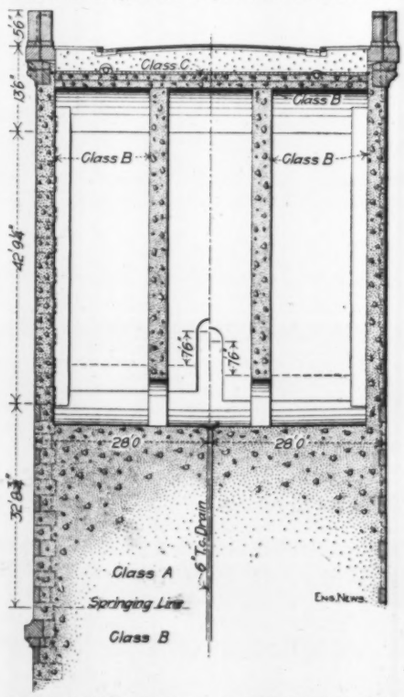


Fig. 8. Transverse Sections Through Pier.

Briefly described, the concrete blocks are placed first and the concrete deposited in place is formed around and back of them. The forms for this work consist of tongued and grooved lagging held by 2 × 8-in. studding on 18-in. centers, this studding being supported in turn by waling timbers spaced 8 ft. in centers and held in place by rods going through the walls. The arch rings are built, of course, on arch centers. After the concrete deposited in place has hardened it will be bush-hammered like the blocks. Up to the present time one U-abutment has been constructed and one of the largest abutment piers has been carried up to the springing line of the 82-ft. arch. Three of the smaller piers have been completed to the springing lines of the 150-ft. arches, and about two-thirds of the centering for the arches is in place.

The general design of the 150-ft. arch centers is given by the drawings of Fig. 12. These centers are founded on piles, excepting for the small arches where timber grillages are used and for those portions in the line of the creek and under the iron bridge that crosses beneath the arch bridge, where concrete footings are used founded on hard rotten rock. The centers are composed of Georgia pine, except a few struts which are Virginia pine, and the sills, caps and wedges which are of white oak. Before framing the centers were laid out to full size on the floor of the Washington Convention Hall, and a pattern was made for each piece. The arch stones were outlined on this same lay-out and templets made for them.

The various details of forms and concreting not already explained are shown by the illustrations. Only a few particulars of the work call for special notice. To hold the forms in place iron rods were carried through the walls. These rods are in two pieces connected by a threaded-shoe set about 3 ins. in from the showing face of the work. This arrangement enables the front section of the tie rod to be screwed out of the concrete and the hole to be filled with mortar. It will be noticed that the lower parts of the arch rings are built up with the piers, they being formed by curved forms held back to the piers by wall ties. The view, Fig. 13, shows the sheet iron forms used in placing the facing mortar on the arch soffits. Similar plates are used for the facing of the vertical exposed walls. Fig. 14 shows one of the arch facing blocks being set and also the tie rods holding the soffit form in place. In cases where the facing mortar was laid in cold weather it was protected from freezing by tacking tar paper to the forms so as to leave an air space between it and the face lagging. Test showed a difference in temperature of 15° F. between the air in the air space and the outside atmosphere.

THE BERING RIVER COAL in Alaska comes from a field 12 to 25 miles inland from Controller Bay and is the best coal that has yet been found on the Pacific coast of North America. The coal area, as far as known, is restricted to the region north of Bering Lake and Bering River. It includes about 120 square miles. The coal resembles the harder bituminous coals of the East more than it does anthracite.

FIRE PROTECTING COVERINGS FOR WINDOW AND DOOR OPENINGS.*

While considerable progress has recently been made in the development of various methods of protecting openings in walls against fire, these developments have been mainly along the line of improvements in existing practice and your committee cannot but feel that far greater advancement must be made to place this engineering problem abreast with the times. Methods and materials are still being commonly used and approved which are unsuited for the purpose for which they are intended. The fire protection engineer and the insurance man may be partly to blame for this condition of affairs but a large proportion of the blame must be attributed to the failure of the manufacturers to make progress in the advancement of their craft by the development of devices which will withstand actual fire service conditions rather than to rely alone on those which appear well under theoretical analysis. Costly experience has too often shown a lack of proper foresight in the failure to conclusively demonstrate the fire-resisting qualities of such devices before introducing them in service.

The recommendations which we have to submit at this time are confined mainly to certain alterations and additions to the present standard requirements and to such rules for the construction of devices as seem to be warranted by the results of tests or by experience in the field.

*Abstract of Committee Report presented at the annual meeting of the National Fire Protection Association, New York city, May 23-25, 1905.

Recent tests and investigations indicate that for openings of ordinary size the so-called standard tin-clad door and shutter, all things considered, furnishes the most reliable protection, particularly when the exposures are severe. The superiority of this type is very largely due to its efficiency as a non-conductor of heat. This offsets in a large measure inherent defects in other respects, such as the bulging of the plates by the gases generated from the inflammable materials now used in its construction, the falling down of the core after it has been reduced to charcoal, and its comparative lack of endurance under severe exposures.

It is only fair to say that recent tests have shown that certain forms of doors have superior fire retardant qualities to the tin-clad, wood filled fire door, but their practicability in other respects has not as yet been fully demonstrated.

Doors and shutters having the desired fire retardant qualities, a more acceptable appearance and in which no inflammable materials are used are urgently needed, and it is along the line of obtaining construction embodying these qualities that it would seem that the most effective progress could be made.

The standard vault door and the iron shutter would seem to take second place as fire retardants for general use, their most objectionable feature being the transmission of heat. When properly constructed, retardants of this class are substantial, durable and capable of considerable variation in design. Combination with some incombustible material having the property of preventing radiation would seem to present the greatest possibilities in their further development.

Wired glass properly framed is classified as third on the list of retardants now in common use. [illegible] iron shutters its most objectionable feature [illegible] the fact that where severely exposed the passag[illegible] through the glass is extreme. There is a vast [illegible] the intelligent use of this most excellent mat[illegible] its limitations should be clearly recognized. A [illegible] tion of many of the present practices in its use will [illegible] doubtedly result in disaster and possibly in the [illegible] of its real value. Wired glass mounted in frames [illegible] are so poorly designed and constructed that they [illegible] hardly hold together until installed in the wall, and [illegible] frames which when heated are unable to withstand [illegible] the smaller jets from fire stream, will hardly prove [illegible] sufficient value to warrant the consideration with wh[illegible] they are now so commonly favored. The use of inflammable putty in which the glass is almost always set [illegible] itself constitutes a danger which is a serious menace [illegible] der many conditions of service.

Polished plate and prism glass in units not exceeding 4 ins. square, electro-glazed and properly framed should, in our opinion, be classed with wired glass as a fire retardant.

Although not at present very generally used or recognized as a fire retardant the steel rolling door and shutter undoubtedly fills a valuable place in the list of retardants. It is classed next to wired glass and is best suited as a protection to exterior openings and where the exposures are moderate. Under some physical conditions it is the only retardant that can be used with any degree of effectiveness. Like the retardants made of thin iron and of glass, its greatest defect is due to radiation.

Your committee has drawn up rules for the construction of fire retardants of this class based on the results

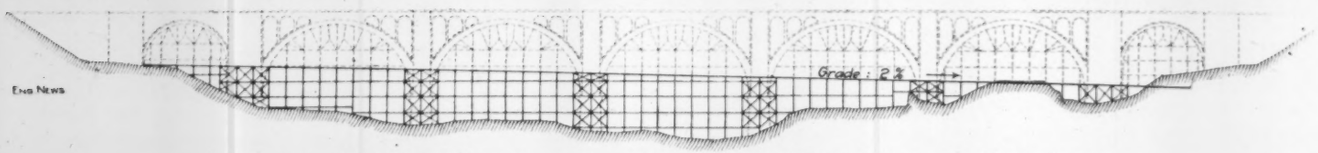


FIG. 9. DIAGRAM ELEVATION OF TRESTLE FOR DELIVERING MATERIAL TO BRIDGE WORK.

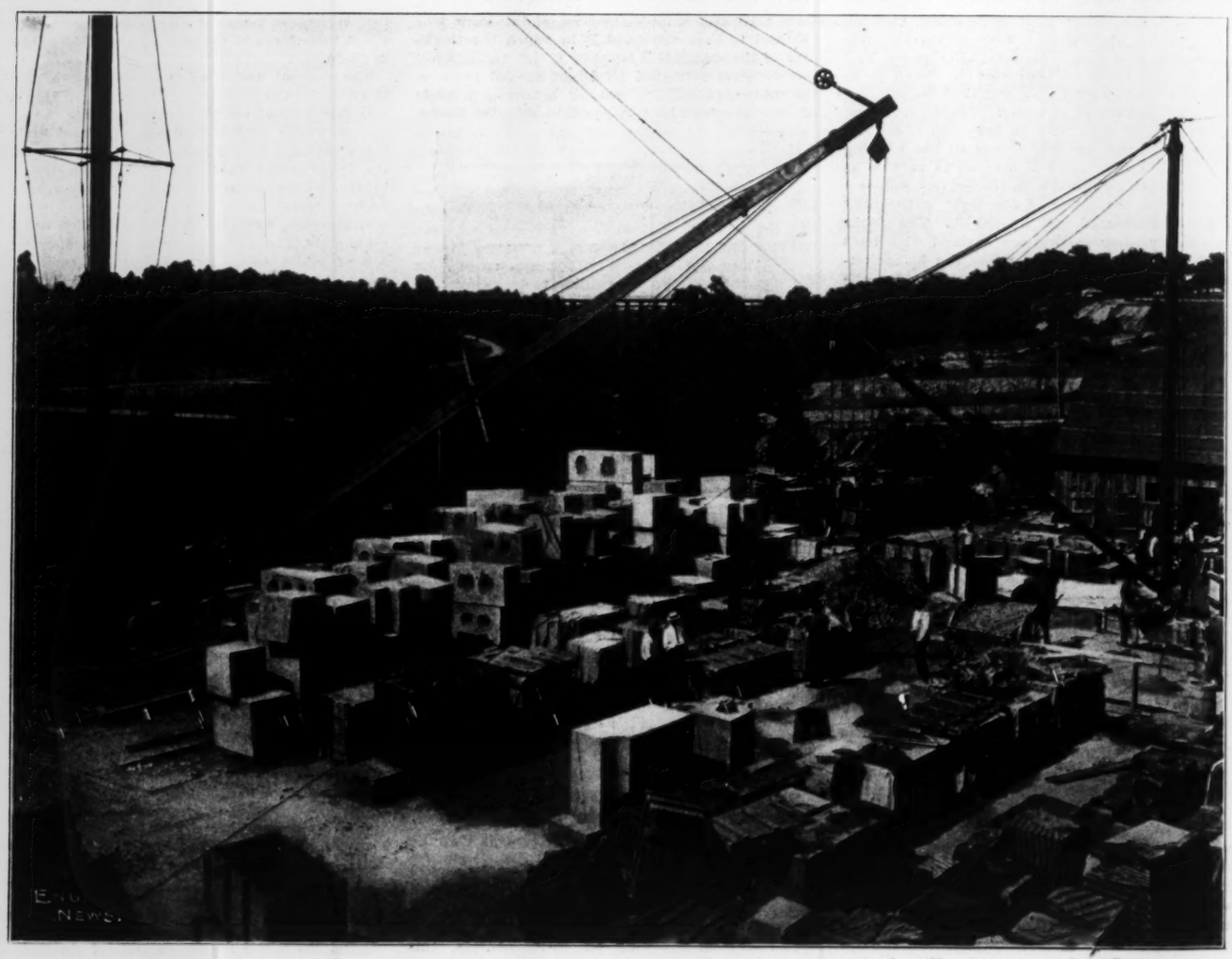


FIG. 10. VIEW OF YARD FOR MANUFACTURE OF CONCRETE BLOCKS, CONNECTICUT AVENUE BRIDGE.

Fig. 11. View Showing Original and Improved Form of Trimming Stone.

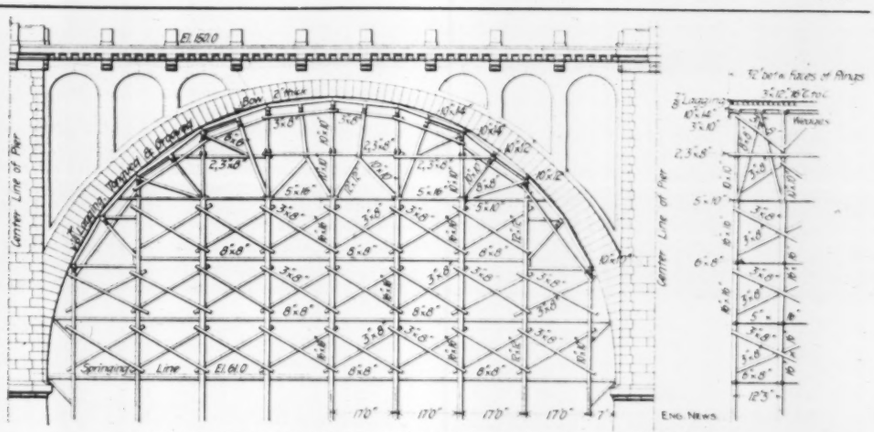


FIG. 12. DETAILS OF CENTERS FOR 150-FT. CONCRETE ARCH.

of tests and field experience. Attention will be called to these later in this report.

Other retardants having considerable merit have received consideration by your committee, some are undoubtedly entitled to a classification but their development has not reached such a point that your committee feels warranted in presenting them for your consideration at this time.

Attention might also be called to the possible desirability of a combination of retardants but we are again confronted with the lack of data on which to base any positive opinions. The committee having the subject of open sprinklers in charge will present an interesting report along this line.

Another subject requiring attention is the preparation of rules for special design of fire retardants made necessary by the various unusual forms and sizes of wall openings now becoming so common. The practical nullification of the value of some forms of fire retardants by placing highly combustible curtains, wood trim, and even merchandise in close proximity to them must not be overlooked in installation work.

While your committe does not wish to advance these opinions as in any way final it feels that exposures should be treated by the careful use of these retardants somewhat in the order of their mention. This with a full appreciation of the limitations of the devices in question.

It may not be out of place to again call attention to some of the more important desirable qualities which should be embodied in fire retardants for the protection of door and window openings. The following general points are therefore mentioned:

(1) They should be made of non-flammable material.

(2) They should be a good non-conductor of heat.

(3) In addition to their fire retardant qualities they should be able to resist the shock and force of fire streams.

(4) They should be so constructed and mounted as to effectively cover the opening protected.

(5) Their ultimate fire-resisting point should be nearly if not quite equal to the fusing point of the materials of which they are made.

(6) They should be capable of withstanding the expansion due to heat and contraction due to rapid cooling.

(7) They should be capable of resisting all reasonable blows from falling members.

(8) They should be easy to operate, capable of being made automatic, acceptable in appearance and should not be prohibitive in price.

Your committee desires to call your attention to the fact that the present standards are intended to apply only to the particular patterns of such appliances as are referred to therein. This explanation is made in view of the fact that certain forms of fire stops for window and door openings have appeared on the market made of materials and embodying forms of construction not at present recognized by the rules, and in fact differing widely from the patterns referred to in the present specifications.

SPECIFICATIONS FOR THE CONSTRUCTION OF INSIDE OIL ROOMS.*

These specifications are intended only for the small inside oil room designed for the storage and safe keeping of the daily supply of oils, paints, varnish, etc., and also for the storage of paint cans, or pots, oil cans, workmen's oily or greasy overalls, aprons, etc., at night. The main supply of oils, varnish, paints, etc., must be kept outside the main building or buildings. Gasolene, benzine, naphtha or similar compounds, except in small quantities in approved safety cans, must not be stored in oil room or in factory.

LOCATION.—To be located preferably in corner of room, not subjected to heat above normal, and farthest removed from any exposing building, and from such processes as require the use of heat or naked lights, (other than approved electric).

SIZE.—Area not to exceed 100 sq. ft., unless by special permission of underwriters having jurisdiction.

WALLS.—To be of hard burned brick, laid flat in good cement mortar, or of concrete, or of fireproof tile, or of other approved incombustible material, substantially built and bonded to and with main walls of building when such form one or more sides of oil room. Walls to extend from floor to the under side of ceilings in buildings of slow-burning or "Mill" construction, or in buildings of fireproof construction, and to extend from the floor to within 6 ins. to 4 ft. of ceiling or bottom of ceiling joist, for buildings of joisted interior construction.

FLOOR.—To be of cement or brick or other approved incombustible material laid in cement upon a galvanized corrugated iron plate resting directly upon the main floor of room. The floor of oil room must be at least 2 ins. in thickness at the drain and be graded (having a pitch of at least ½-in. per foot) to center or one corner of room. Top surface of floor to be finished with hand troweled neat cement or other approved material and made water tight.

CEILINGS.—If other than incombustible material—for slow-burning or "Mill" construction buildings—all woodwork to be covered by lock jointed tin plates, nailed under seams in an approved manner. No solder to be used. Use tin plates 14 × 20 ins., "IC" charcoal 108 lbs. to box. Avoid air spaces by nailing tin plates directly to plank ceiling.

For oil rooms located in buildings of joisted interior construction, or in buildings having sheathed or plastered ceilings, to be of 3-in. splined and grooved or tongue and grooved planking covered on underside in an approved manner by lock jointed tin plates. Ceiling to be inclined. Space between roof of oil room and ceiling of main room must not be used for storage or other purposes.

WINDOW.—In one of the outside walls farthest removed from any adjoining or exposing building there shall be provided a thin common glass window in all metal frame; area of window to be not less than 4 sq. ft. and not more than 12 sq. ft.

DRAIN PIPE.—To be of 4 or 6-in. diameter wrought iron or steel threaded pipe (do not use flanged or lead jointed pipes), firmly imbedded in cement floor at lowest point; the orifice of pipe to be protected by a wire screen or guard. Drain pipe to be kept clear of all woodwork or combustible material and extended outside the walls of building to a point well removed from all buildings, or to a special safely arranged and vented receptacle approved by the underwriters having jurisdiction.

VENTILATOR.—A metal pipe or duct having an area at least equal to a 4-in. diameter pipe shall be provided

*Report presented at the annual meeting of the National Fire Protection Association, New York city, May 23-25, 1905.

FIG. 13. VIEW SHOWING CONCRETING AT BACK OF ARCH.

FIG. 14. VIEW SHOWING ARCH RING FACING BLOCK BEING PLACED.

at or near the ceiling line, the ventilating pipe or duct to be extended outside the wall of building with the outlet looking down; the ventilating pipe or duct must be protected at each end by a close mesh wire guard.

DOOR FRAME.—To be well constructed of riveted ⅜-in. thick, iron or steel channels, built into wall in such a manner that the sill (or threshold) shall be at least 2 ins. above the oil room floor and at least 6 ins. above main floor. Channels to be of sufficient width and depth to snugly fit over the wall, the flange of channel must overlap the wall at least 3 ins. on each side.

Door frame may be constructed of angle iron of same dimensions as the channels, provided the two angle iron frames be held firmly in place by at least three ¾-in. bolts, each side, passing through the wall.

At least two hinges (for door) and one catch for latch shall be riveted to the door frame. Hinges to be made of ⅜-in. or heavier iron, at least 3½ × 2½ ins., and must be riveted to frame by at least three ½-in. diameter rivets.

DOOR.—A standard tin clad fire door of the self-closing, swinging pattern, properly supported on door frame, by hinges of 2 × ⅜-in. bar iron extending three-quarter way across and bolted to fire door and provided with a proper latch as per specifications on page 8 and as illustrated by Fig. 30, in booklet containing "Rules and Requirements," for the construction and installation of "Fire Doors and Shutters." Door to close flush with wall and to have 3 × ¼-in. bar iron all around outer edges of door, lapping over wall frame at least 1-in. and secured to door by bolts not more than 12 ins. apart.

PORT HOLE.—A small port hole not exceeding 2½ ins. in diameter (a section of 2 or 2½-in. pipe with metal cap or cover) may be built in wall, for the purpose of introducing a hose stream into oil room.

PROTECTION.—One or more approved automatic sprinklers must be properly installed and connected to and with the water supply by not less than a 1-in. pipe having a controlling valve in main room near oil room. If the water supply be not maintained at all times, with a pressure of at least 20 lbs. per sq. in. at oil room, then the sprinkler piping must also be connected to and with the steam boiler or boilers and have proper valve at boiler room and at oil room.

SAND PAILS.—Two or more covered pails of clean dry sand (with scoop) to be provided and placed in or immediately outside of oil room.

CHEMICAL EXTINGUISHERS.—One or more 3-gallon approved carbonic acid gas hand fire extinguishers shall be provided and kept in oil room, or on bracket or shelf, near the door to oil room.

CARE AND ORDER.—Racks, stands, or shelves for barrels, cans or pots should be constructed of metal or incombustible material. Room must be kept orderly and clean and cared for by a trustworthy man. Door of oil room should not be blocked open but must be kept closed when not in use. One approved metal self-closing oily waste can must be provided; the spent waste in can to be taken to boiler room and burned under boiler each night or otherwise properly disposed of. Sawdust, shavings or similar material must not be used for absorbing oil drippings.

Smoking prohibited. "No Smoking" sign must be posted in oil room and on outside of door to main room. Room may be lighted by approved incandescent electric lights in keyless sockets controlled by switch outside. Open lights must not be carried into oil room.

CAUTION.—The use or storage of gasolene, naphtha, benzine, and other inflammable liquids even with all known precautions is a danger which should always be recognized. At ordinary temperature gasolene continually gives off inflammable vapor, and a light some distance from the material will ignite it through the medium of this vapor. The vapor from one pint of gasolene will make 200 cu. ft. of air explosive. It depends upon the proportion of air and vapor whether it becomes a burning gas or destructive explosive. Beware of any leaks in cans, and never forget how dangerous a material you are handling.

IRRIGATION SURVEY OF THE UPPER SNAKE RIVER VALLEY, IDAHO.

By E. B. Darlington.*

During 1904 irrigation investigations on a large scale were made under the direction of the state engineer of Idaho, and the recent completion of the office work has put the data into such form that they may be reviewed. The examination was undertaken at the request of the Court of the Sixth Judicial District of Idaho, and its primary object was to furnish evidence in the adjudication of the water rights of the Upper Snake River Valley.

The survey embraced the measurement of all irrigation ditches and canals diverted from Snake River and its many tributaries above American Falls, and a determination of the irrigated and irrigable areas dependent thereon. Detailed reports upon the capacity, condition and scope of all irrigation works and descriptions of the land involved were also required.

The compiled statistics show that 290,679 acres are at present irrigated in that locality, 502,501 acres are susceptible of irrigation, and over 50,000 acres lie under mountain streams which are inadequate for irrigation purposes. In the accumulation of the data probably 1,500 square miles were covered. About 250 canals, having a total capacity of 20,010 sec.-ft., were thus measured and their courses and dependent lands accurately mapped.

The field work was begun about the middle of March, 1904. At that time five parties were organized, but this number was afterward increased to six. Each party consisted of a transitman, a field draftsman and two stadia rodmen. It was found that at times a third rodman could be used advantageously, but on the whole four men proved to be the most economical and mobile party organization.

Each party was assigned to a territory estimated to contain two or three weeks' work from one camp, but an effort was made to distribute the parties in such a way that two teams could handle them all. This arrangement was found to be quite satisfactory and resulted in a considerable saving for team hire. In emergencies extra teams were engaged from the farmers without difficulty.

Usually when a party commenced an assignment the headgate or point of diversion of the most important canal in the territory was tied to the nearest section corner by course and distance, the true meridian being determined by solar observation. The alinement of the canal was then run out, each plate angle of azimuth and stadia distance being read by the transitman to the field draftsman, who responded by calling the calculated course, which was checked by a glance at the needle, the magnetic declination being set off on the plate. The draftsman then platted the readings and sketched in the canal, the laterals and such other features as were thought desirable. The field maps were drawn upon a scale of 500 ft. to the inch. Ties were made to section corners whenever practicable, so that errors of field work or drafting were almost immediately detected.

After all the canals in a given territory were accurately located and the points of departure of laterals indicated, needle traverses were run along controlling lines, from which radial shots to determine boundaries were recorded and platted. Contour traverses were sometimes necessary to cut out land above the gravity lines of canals. Land was classified as irrigated hay, irrigated tilled, dry but irrigable and non-irrigable under existing systems. The boundaries of these tracts were indicated on the maps by different-colored pencils. The draftsman also sketched in the feed laterals to show how and by what systems the lands were watered. Notes as to the character and porosity of the soil were taken by the transitman. It was found that ordinarily about two square miles could be mapped by each party daily, after the canal lines had been run.

Measurements for capacity were made at representative points along each canal. In determining cross-sectional areas, rod readings were taken at 2-ft. intervals on large canals and at 1-ft. on small canals, and the mean of several measurements was assumed to represent the true cross-sectional area. The grade for several hundred feet was then determined, and the condition of the bottom and sides of the channel minutely described as a basis for the evaluation of the coefficient of friction (n). By these means complete data were obtained for computing Q by Kutter's formula. The use of meters in gaging velocity was impracticable, as canals were seldom or never flowing at their maximum capacity.

Measurements, sketches and descriptions were also made of diversion dams, headgates, wastegates and flumes in order to show the condition of works.

In the office profiles of every cross-section were constructed and the computations of capacity were made. About 245 detail maps, showing the land in colors to correspond with the canals they serve them, and an index map of the whole [illegible] on a much smaller scale, was made to [illegible] reference to the detail sheets. Progress maps are also furnished to the U. S. Geological [illegible] monthly.

Perhaps the most remarkable feature about the undertaking was its comparatively low cost, no doubt due principally to the size and scope of the undertaking, making an economical organization possible. The total expense of the survey was $28,000, which divided by the number of acres involved gives a cost of approximately [illegible] per acre. The Reclamation Department of the U. S. Geological Survey assumed a portion of the cost, amounting to $9,735, in order to obtain the information for its immediate use, and the balance is assessed to the litigants. As the maps are of public record, every land owner in the Upper Snake River Valley has the benefit of an excellent map of his property at a cost to him of 2.3 cts. per acre. In other words, every 80-acre farm was surveyed and mapped for $1.85.

The work was under the direction of Mr. James Stephenson, Jr., State Engineer. The writer had immediate charge of the survey as chief engineer, and was ably assisted by Mr. Z. N. Vaughn, of Boise, field supervisor; J. W. Shepperd and H. C. Smith, of Moscow, Idaho, W. N. Gibb, of Genessee, Idaho, J. P. Taylor, of Pocatello, Idaho, Lindsey Hudson, of Salt Lake, Utah, and A. D. P. Janney, of Leesburg, Va., instrumentmen.

*Irrigation Engineer; Field Manager for State Engineer of Idaho.

PRIZES FOR PAPERS on the subject: "Lime vs. Gypsum Plaster" are offered by the National Lime Manufacturers' Association. The first prize is $100 and the second $50. The papers must be submitted before June 30. A full statement of the conditions of the competition can be obtained by addressing Mr. Charles Warner, President of the National Lime Manufacturers' Association, Wilmington, Del.

A WIND-PRESSURE DANGER-SIGNAL has been installed on the Levens viaduct of the Furness Ry., in Scotland. About two years ago a passenger train standing on this viaduct was overturned by a violent squall, and the apparatus here noted is intended to prevent the recurrence of such an accident. The device comprises a recording wind-pressure gage, to which is fitted an electric contact which closes when the pressure reaches 32 lbs. per sq. ft., and an electrically actuated warning bell at each end of the viaduct which is set ringing when the pressure-gage contact is closed. The pressure-gage consists of a vertical angle-iron frame, in each of two opposite faces of which is fitted a vertical board hinged at the top and resting against a spring at the bottom. Each board is 18 ins. wide by 24 ins. high, or 3 sq. ft. in area. A recording apparatus is mounted in the interior of the frame. Its two pens are actuated by the two gage boards; the drum moves the paper at the rate of 1 in. per hour. The instrument is tested periodically by a weighted lever arrangement which applies a pressure of 32 lbs. per sq. ft. to the board, the pressure which is intended to be the limit at which the bells are set ringing. The recording instrument was made by Elliott Bros., of London, and the whole apparatus was installed by J. B. Saunders & Co., of Westminster. It is stated that since the erection of the apparatus, more than 18 months ago, at no time has the wind-pressure exceeded 5 lbs. per sq. ft.

MAINTENANCE ON AUTOMOBILE FIRE APPARATUS in Hanover, Germany, is reported as follows: The department bought an automobile chemical engine and an automobile hose-cart early in 1902. Both were propelled by electric current furnished by storage batteries. The expenses for maintaining the vehicles and supplying current during the three years they have been in use are summarized in the table following.

First Cost.:

Hose Cart (without hose)	$2,585
Chemical Truck (without apparatus)	$3,735

Operating Statistics, Total for Both Vehicles:

	1902	1903	1904
Miles run	2,340	1,930	2,040
Motor Repairs	$3.96	$4.52	$90.74
Controller Repairs	5.29		
Tires (rubber)	45.25	52.00	20.50
Other Vehicle repairs		9.87	
Current: Service	171.15	153.87	130.02
Testing	40.65	18.87	44.13
Battery maintenance	23.05	3.96	183.58
Lubricant, etc.	5.62	7.00	7.37
Total Operating Expenses	$294.97	$250.09	$476.34

The vehicles have proved satisfactory, it is said. The high motor repairs in 1904 are due to the fact that the motors became wet, and the armatures had to be rewound.

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A notable example of the use of molded concrete blocks is presented in the construction of the Connecticut Avenue arch bridge described on another page of this issue. It was the preferred plan of the designing engineer and the hope of the Washington officials to construct this monumental work of granite masonry, but the funds allowed by Congress put the use of so expensive a material out of consideration. The engineers of the work were practically compelled to resort to concrete, and about the only choice left them was whether they should use plain monolithic concrete, a combination construction of monolithic concrete and cut granite work or a similar combination of monolithic concrete and molded concrete block work. The combination all-concrete construction was chosen, and we believe that the wisdom of the choice will be manifest when the completed structure is finally on view. As will be observed from the drawings which we publish, the main body of the bridge is of plain concrete in mass with the essential structural elements picked out by molded concrete blocks. The point on which the engineers must stand trial is, of course, whether the choice of molded concrete blocks instead of cut granite was justified. From the point of view of economy there can be no doubt of the wisdom of choosing concrete blocks. Cut granite voussoirs, quoin stone, dentils, brackets, etc., of the forms adopted would cost something like $80 per cubic yard; the molded concrete blocks are costing, without dressing, about $15 per cubic yard. Judging from experience with similar work, the cost of bush hammering the concrete blocks should not exceed 3 cts. per square foot. Even if the cost of dressing the molded blocks should considerably exceed this figure, the cost of block construction as compared with cut granite would be very small. Another point which is possibly worth something in favor of the use of concrete blocks is that they make a more homogeneous structure in combination with mass concrete; there should be in consequence less danger of cracks due to shrinkage or the compression of the material under stress. The prime question of course is whether the same beauty of appearance can be secured with dressed concrete blocks as with dressed granite. An examination of the finished blocks placed in the bridge gives no alarm as to their possible inferiority in appearance to dressed granite. They present a somewhat duller and more dead appearance, but the difference is not so striking but that an observer not familiar with the texture of stones might easily mistake the concrete blocks for granite. It is possible, of course, that a long period of weathering might bring out more striking differences, but in freshly dressed stone they are hardly great enough to warrant consideration. Moreover, in case weathering does cause a substantial alteration from the appearance of the freshly dressed blocks, this change will be in harmony with the weathering of the mass concrete, which has the same composition and finish as the blocks, and this might not be so with cut granite and concrete in combination. All things considered, the most serious cause of alarm as to the appearance of the new bridge exists in the possibility of efflorescence. This form of defacement now appears in many places on the portions of the piers and abutments that have been erected, and is exceedingly unsightly. All of these stains will, of course, be removed in the final tooling and cleaning of the finished bridge, and were we sure that the cure would be permanent there would be small cause for concern. Unfortunately all experience shows us that we cannot be certain of permanent results by any means now known to experts in concrete work. Obviously the use of cut granite in place of concrete blocks would have made no great difference in the amount of efflorescence, so that the engineers deserve no criticism in this regard.

The agitation for a tunnel to connect Prince Edward Island with the Nova Scotia mainland has recently been renewed. A dozen years ago the people of the island made a strong appeal for the Dominion Government to undertake the work; but the uncertainties of submarine tunneling at that time were so great that the Government refused to subsidize the work, and there is practically no possibility of its construction by private enterprise.

During the past winter the steamer communication between the Island and the mainland was interrupted for two months by ice gorges in the straits, and it is stated that the accumulation of traffic was so great that it is not yet all cleared away. Freight arrived at Pictou in January which may not reach the Island till June.

In our issue of June 29, 1893, we published a full account of the projected tunnel and of the borings along its route, which were made for the Government by Mr. Alfred Palmer. The tunnel would be about 8½ miles in length, and the greatest depth of water in the Strait is 96 ft. The borings showed alternate layers of clay shale and red sandstone, which it is claimed would be impervious to water. It would not be safe to assume, however, that a tunnel could be driven in such rock all the way across beneath the Strait, and the only safe assumption is that compressed air would have to be used to keep the workings dry and at a pressure well up towards the limit at which men can work with safety. This would bring the cost of a tunnel 8½ miles in length to a very large figure.

Prince Edward Island has an area of 2,184 square miles, and a population of about 100,000, a density of population more than twice as great as any other Canadian province. The 211 miles of railway on the Island carried 106,519 tons of freight and 205,265 passengers in 1903, and had gross earnings of $217,714 and operating expenses of $259,638. It is doubtful whether a tunnel could be built under the Northumberland Strait, even if no extraordinary difficulties were encountered for less than $10,000,000 total outlay. This would be an expenditure of nearly $5,000 per square mile of the Island's total area, or $100 for every man, woman and child of its population. It is a fair question whether the total benefits conferred would justify so great an outlay.

There has been talk of building a great rock embankment across the strait instead of a tunnel; but the great depth of the water would make the work even more expensive than the construction of a tunnel. The most practicable plan for giving the islanders better means of access with the mainland would appear to be the construction of an ice-breaking steamer on modern lines. After the experience gained in the construction and use of ice-breaking steamers during the past ten years, it should be possible to build a vessel which could keep communications open between the island and the Nova Scotia coast throughout the winter.

The work and duties of the railway division engineer were clearly and intelligently set forth in a paper read before the Western Society of Engineers on May 3 by Mr. Willard Beahan. We give an abstract of this paper in another column, and while it relates specifically to the division engineer in railway service, the advice and the teaching apply to the engineer in general, whether in high or low position or in any branch of the profession. Mr. Beahan lays stress upon the desirability of personal contact with men, and a readiness to help in emergency or to share responsibility. There is no doubt that in many large organizations there has developed a tendency to multiply correspondence and to increase "circumlocution" by wrapping red tape around matters which should be handled directly and promptly.

The relation of the engineer to the maintenance department of railway service, as set forth in Mr. Beahan's paper, is worthy of careful consideration. The civil engineer has come into prominence in this department during the past few years, and is certain to become still more prominent. The reason for this is that his work has shown that he is an important factor in efficient and economical railway operation. The old idea that the track or maintenance-of-way department is a field only for the foreman and the laborer, and beneath the dignity of the engineer, has not yet been outlived entirely; but year by year the economy to be made by more intelligent planning and supervision in this department is realized, and more engineers find places in this field.

FORTY THOUSAND PRACTICING ENGINEERS AND FIFTEEN THOUSAND ENGINEERING STUDENTS: WHAT SHOULD THIS RATIO MEAN TO INSTITUTIONS FOR ENGINEERING EDUCATION?

The number of students taking engineering courses in American colleges and universities has increased at a most remarkable rate during the last few years. Each year has followed the precedent of the last in point of numbers in the entrance classes, but in almost geometrically increasing ratio. What are the causes, and what will be the results of this emigration of young men from other possible trades and businesses into the profession of engineering?

The causes are many, but two stand out in relief before all others. As a nation we have reached a preeminent position because of the application of science to production in factories, fields and mines. The word production as here used includes transportation, which is merely one factor in the cost of production.

The daily papers keep before the public biographies of the men who have been leaders in developing the machines and systems used in producing wealth. Applied science has rightly come to be regarded as one of the principal causes of material success; and young, ambitious men have been, in consequence, attracted to the schools and colleges of engineering.

Second only to this indirect advertising of the worth of science, has been the direct advertising by many of the colleges of engineering, which issue frequent bulletins that are reprinted, more or less in full, by the daily papers of the states in which these colleges are located. Nor should we exclude from this class of direct advertising, that done by the correspondence schools with their legions of hustling agents.

Thus has education in applied science been advertised as no kind of education was ever advertised before. The results are apparent. In 1902 there were 15,000 students in American engineering colleges, as shown in the accompanying table. This number does not include, of course, the students of correspondence schools; nor does it include the students in a great number of schools below collegiate grade where instruction is given in mechanical drawing, electricity, mechanics and various other elementary branches of engineering.

Neither does it include the not inconsiderable number, who, through apprenticeship courses in manufacturing establishments and laborious self-education, are preparing themselves to compete with the men who have had the advantages of a regular course in an engineering college.

Number of Students in American Engineering Colleges.*† 1901-2.

Course.	Special.	Year. I	II	III	IV	Total.
C. E.	804	978	904	604	404	3,694
E. E.	490	876	640	380	262	2,648
M. E.	1,049	1,030	953	663	468	4,163
E. M.	231	472	343	279	128	1,453
Nav. Arch.	4	38	13	16	10	81
Arch.	55	93	85	63	66	362
Chemistry	9	21	33	30	22	115
Chem. Eng.	67	58	45	38	30	238
Special Eng.	766	998	151	149	95	2,159
Total	3,475	4,564	3,167	2,222	1,485	14,913

*Abstracted from Proc. Soc. Eng. Education, Vol. X.

†Since this table was compiled, the Report of the Commissioners of Education for the year 1903 has been published, containing the following additional figures:

Under Graduate Students of Engineering, 1902-3.

Mechanical engineering	6,800
Civil engineering	5,278
Electrical engineering	3,652
Mining engineering	2,244
Chemical engineering	725
Textile engineering	133
Sanitary engineering	27
Total	18,859

It is interesting to note in addition that there were only 558 students of architecture.

Here we see almost 19,000 students of engineering reported as entered the college year of 1902-3. It is probable that the enrollment this fall will be not less than 23,000, and it may be considerably more if the rate of increase has been as great these past three years as it was during the ten years preceding 1902. At any rate the number will exceed 20,000, and will therefore be more than half the total number of practicing engineers reported in the last U. S. census!

While this table is not complete, it serves to show the enormous increase in the entering class (I) over the classes of earlier years, and to indicate the relative popularity in the different collegiate courses of applied science. Mechanical engineers (4,163 in number) head the list; civil engineers (3,694) follow; electrical engineers (2,648) are not a bad third; and mining engineers (1,453) are much more numerous than one not familiar with recent progress in engineering education would suppose. Architecture and chemistry are comparatively neglected, but it should be observed that there appears to be some error in the classification of chemists, because we note the omission of any returns from certain of the colleges known to have many students studying for degrees in chemistry.

We have not at hand the number and classification of students for the years since 1902, but, almost without exception, engineering colleges have reported great increases in the entrance classes each year. For our present purpose perhaps the table above given serves sufficiently well.

Now let us compare these statistics with some taken from the United States census reports for the year 1900. We find the number of engineers and architects in the whole country given as follows:

Civil engineers	20,153
Surveyors	6,034
Mechanical and electrical engineers	14,440
Mining engineers	2,904
Chemists, assayers and metallurgists	8,887
Architects	10,604
Designers, draftsmen and inventors	18,956

The total number of engineers and surveyors, as above given, is 43,535; but it is safe to say that a great many of the surveyors and many of the engineers are not strictly entitled to be classed as engineers. Probably 40,000 would fully cover all the engineers in the United States in the year 1902, as compared with 15,000 students of engineering. Since the growth in the number of students taking engineering courses has steadily increased since 1902, we are safe in saying that nearly 4,000 young men are going out yearly with the expectation of finding engineering positions. What are the chances that their hopes will be realized?

The growth in the number of wage earners in America for many years has been about 3% per annum. We may, therefore, say that 3% of 40,000, or 1,200 engineers are required to maintain the same ratio of growth, but, as about 2% of adult deaths will occur annually, we must add 800 more to fill the ranks. As against these 2,000 new engineers required, there is an annual output of 4,000. The surplus can find engineering occupation only by crowding out other men not so well trained, or by creating engineering positions for themselves; for the natural growth of purely engineering enterprises can not possibly keep pace with the growth in the number of engineering graduates. We fear that much deceptive information has been spread abroad as to the number of positions awaiting young engineers on the day of their graduation.

It will be said, perhaps, that the same sort of argument can be advanced to discourage the young lawyer or the young physician. Let us see what there is to such a statement. The last census shows that there were 114,703 lawyers and 132,225 physicians and surgeons. Prof. Ira O. Baker has published a table showing that in 1890 there were 11,833 students of law and 26,088 students of medicine, the graduates for that year numbering 3,110 and 5,725 respectively. If we take 5% of the total number of practicing lawyers and physicians above, we see that the number of graduates is no more than is required to keep pace with the natural annual growth. This disposes of the argument that the engineering profession will not be more overcrowded by graduates than any other profession.

The inevitable result of the facts above set forth is a severe competition among engineers for employment. It is a case of survival of the fittest, and the fittest often means not the man with the greatest ability but the one with some personal influence or the possession of some independent means that enable him to get or maintain a foothold that another cannot reach. That the net result is to lower the scale of wages and salaries in all branches of engineering work is a fact patent to all.

It seems to us that there is a lesson in the above statistics for those in charge of our institutions for engineering instruction. For the most part the courses in these institutions have been shaped to fit the student for professional work as an engineer. But if a half or even a fourth of those who graduate annually from these institutions must earn their living in other occupations than engineering, ought not that fact to be recognized? Ought not the course to be made such as will help these men in their life work, as well as the men who do find places in engineering work?

Let us put the case another way. Fifty years ago there was no general education of collegiate grade except the old-time classical course; and the boy who went to college took that without question. At the present day a great proportion of the boys who go to college are taking engineering courses in preference to any other.

Should they be given a narrow professional training or a broad education that will fit them as well to cope with the world in any field of work, as well as or better than if they had chosen the study of Latin and Greek?

Young men are flocking to our engineering colleges, because they offer, or are supposed to offer, the best courses in applied science. Other collegiate courses in pure science—the so-called science courses—are largely neglected. The great majority of men must be bread winners, and can not afford to spend four years on culture studies and pure science to be followed by perhaps as many more years of apprenticeship before they can earn a salary that will give some degree of independence. They must get results sooner, and the engineering college gives them a training intended to fit them for immediate usefulness. But if the field of immediate usefulness remains as narrow as it now is, there is certain to be much loss of valuable time on the part of the new graduate, on account of the great excess of supply of men over demand.

Indeed, we risk little in saying that the average holder of a civil engineering degree spends half of his first three years looking for a job. A month or two of surveying or drafting is followed by as long a time seeking another position, which when found, yields less money than a union hod carrier gets. And, so long as the number of engineering students remains proportionately as large as at present, the majority of graduates must ultimately find or create positions for themselves in other lines of business than engineering. In a word, the "woods are full" of engineers seeking to follow a purely professional career. The only avenue of escape from an already se[vere] and throat-cutting competition lies in findi[ng] [pla]ces where applied science can be used to ad[van]tage in other kinds of production than the ki[nd] commonly thought of as being "engineering."

We say "commonly thought of," but, a[s] [a] matter of fact, the definition of engineering [is] for the broadest definition of engineering, [there] is scarcely a line of human activity to wh[ich] engineering knowledge can not be applied [to] advantage. If so, it will be asked, wherein [are] any of our engineering colleges defective, or [the] students misguided. This brings us to the re[al] point at issue.

A careful examination of the catalogs of engineering colleges, makes it apparent that there is, for the most part, comparatively little in the way of instruction that prepares for a business engineering career—yet, if the statistics above given are correct, the great majority of the engineering graduates of the future must find occupations in business and not in professional work.

We know that the stock argument is that engineering courses are already overcrowded with subjects; that nothing can be omitted; that study of cost keeping, or of business law, or of methods of organizing factories, does not furnish as good mental training as the present studies furnish; therefore that the acquirement of such knowledge and training must be left until after graduation. More than once we have taken issue with this point of view, and we must again pronounce it fallacious.

Mental training is a difficult thing to define, and it is still more difficult to distinguish between the different kinds of training as regards their relative value. A habit is not often spoken of as being the result of mental training, yet so it is, whether it be a good or a bad habit. Habits of thought and action are essential to success and they are better imparted by precept and by example at college than by accident after the college days are over. If the engineering student does not form the habit of looking upon every engineering problem as a problem in economics, he is in danger of never forming such a habit, because at the time of his graduation he is fast passing out of the habit-forming period of his life. Then, if he spends the next three or four years wielding a ruling pen or reading a level rod he reaches an age where old habits become crystallized and new habits form with difficulty, if at all. The fact that the most successful men of business have entered on their business careers at an early age should itself have drawn general attention to the desirability of early training in business methods. Yet in the face of this fact, we hear it solemnly urged that business methods can best be learned after graduation. We deny that this is so. While new methods can be learned late in life, new habits of thought can not be readily acquired after the age of twenty-five. The engineer should receive his training in business habits and methods during his college years, and not be left to acquire them afterward by chance.

When it is proposed to make any addition to a course in engineering the cry goes up, "What would you have us omit?" Fortunately, there is much that can be omitted to advantage in every course known to us. Take drawing, for example. Precedent has made us all blind believers in the worth of all the practice in drafting given; and the criticisms of men who employ draftsmen has had its effect in stimulating engineering colleges in making elaborate provision for training draftsmen. Sum it all up, however, and what does it amount to? The principles of projection and mapping are quickly acquired; it is the practice that takes the time. All concede that an expert hydraulician can not be made at college, because there is not time; then, why should the attempt be made to make expert draftsmen? Nine engineers out of ten will not follow drafting as a permanent occupation; and, on the other hand, the same nine will receive valuable practice in the art of drafting after graduation. The only useful purpose served by long practice in this art at college is the greater worth of the new graduate to an employer of draftsmen. But, if to secure this slight advantage, other and more important kinds of training are neglected, the student suffers greatly in the end.

other subject that receives far more time is warranted is the subject of strains and stresses. If an engineer from Mars were to sit through the lectures and quizzes at certain of our engineering colleges for a week, he would infer that we are essentially a race of truss builders.

That there are a multitude of engineering structures designed almost entirely by "rule of thumb"—that is, by precedent—he would hardly guess. That it requires engineering talent to operate the plants designed by engineers, he might never surmise. Strains and stresses, in big letters are stamped into the young civil engineer's brain until he goes forth believing that since he can compute the necessary size of a Brooklyn Bridge cable he is competent to undertake the construction of any metallic thing on earth.

The courses, good as they are, are lamentably unbalanced. One year in strains and stresses will impart the necessary principles, but will not make an expert bridge engineer; yet that one year should be enough to train the young engineer so that he can afterward understand the most abstruse of text-books on the subject, if chance makes him a bridge designer.

In the same manner we might go through the list of subjects, showing that the average student spends too much time on many subjects to the exclusion of others of greater relative value, both as a trailing and as a means of subsequent success.

A text-book on law and another on cost-keeping and the management of men should form a part of every student's library. In the course of his other work the student should be taught how to apply the rules and methods laid down in these books. For example, in his surveying field work he should be required to keep systematic records of the progress of every item of the surveying and mapping work. In his courses in highway construction and masonry he should be required to keep similar records of materials and labor required for each item of several actual pieces of construction coming under his own observation. Having tabulated results he should be required to analyze the costs—reason about them—with the object of discovering methods of improving the organization of the forces and the handling of machines. The economic efficiency of machines should be tested by cost-keeping, with a view to improving the machines themselves. As it is now, students of mechanical engineering give much of their time to study of fuel efficiencies, when efficiencies are studied; when the fact is that in the work of most machines the fuel item is among the smallest items in the cost of production.

The professor of civil engineering in one of our leading colleges strenuously objected a short time ago to giving his courses a commercial tinge by introducing such training as is above suggested. With some curiosity, therefore, we turned to a recent summary of the occupations of the graduates of this institution. We found that of 560 graduates in civil engineering only 20 are reported as being contractors or in the employ of contracting firms. Does this look like a proof of the contention that the courses now given at that college fit men for business engineering and that business knowledge is better acquired after graduation?

It seems to us that the engineering colleges destined to have the greatest usefulness are those in which the courses in all kinds of engineering shall be essentially the same for, say, the first two years; and that during this time the principles underlying all engineering and the principles of business and production generally shall be taught. During the two years that follow it is probable that differentiations must occur, but still the endeavor should be to train and to form habits rather than to impart dexterity or to cram with facts. The engineering college should not be made a manual training school in any sense; not even drafting or surveying being carried so far as to give any great amount of dexterity. There should, however, be such a variety and such a quantity of manual work in laboratories and in shops as to give a skill of the mind, whether the hand be thoroughly practiced or not.

The man who expects to follow the chemical side of manufacture will add to his two years of engineering the two years of chemical laboratory work and study. The man who is going into mining will give much of his last two years to assaying, ore dressing, and metallurgical laboratory work, supplemented by text-book instruction. And in like manner each field of engineering will have its special studies, although the training in all will be of essentially the same character—a training in scientific and business methods of attacking problems in economic production. Indeed, the fundamental training in scientific principles and business methods should be so broad and so thorough in all the different courses in engineering as to make it a comparatively easy matter for a graduate to enter any of the lines of production. He should not feel that he is tied to any one branch of engineering work irrevocably.

The Society for the Promotion of Engineering Education would do well to collect records of the after careers of engineering graduates and to publish tabular information showing the numbers in each class of occupation, and the shifting that occurs from one occupation to another during the first few years after graduation.

Moreover, the students themselves should be made acquainted with statistics that they may form some rational judgment as to the amount of competition to be encountered in different branches of the profession. The result of such study would show, for example, that too many students are now specializing in electrical engineering, and too few in chemical engineering. The word electricity has dazzled and attracted many who have no knowledge of the limitations of the field for electrical engineers. The mining field is receiving attention, but the possibilities of profit from the application of scientific and business methods to agricultural production are scarcely considered.

The men and the machines that make the products of the world have stood before the civil engineer, and he, because of a lack of the training that begets confidence, has chosen only one part of production for himself—the design of the tools. For what is the location of a railway, and the drawing of plans for its bridges, but a part of the design of one of the greatest of productive tools? In the past the man who has come up from the ranks has built the railway, and another man, equally self-made, has operated it. Yet, in the last analysis, it requires fully as great engineering skill successfully to build and successfully to operate as successfully to design any appliance so intricate as a railway system.

In spots, here and there, we see evidence that the engineer is taking hold of the machinery that he has planned and is operating it. The future holds its greatest rewards in store for those engineers who are first to seize upon the directing of the forces that now are in the hands of untrained men. The rush of engineers into the concrete-steel construction field as contractors shows evidence of an awakening. In Germany the monopolization of certain manufacturing industries, particularly, the chemical industries, by technical graduates, shows the same awakening. But why have we so few engineers engaged in erecting buildings? Why so few in general contracting? Why so few in every class of work requiring business knowledge, self-confidence, and ability to handle men and direct the use of machines?

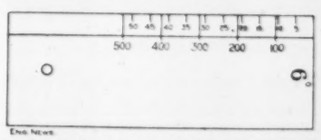
The answer, we take it, is to be found in the unbalanced courses given in most of our engineering colleges, which tend to train mathematical engineers and fail to develop business instincts and habits of thought essential to business success.

LETTERS TO THE EDITOR.

A Method of Plotting Contours Where Slopes of Ground Are Measured in Degrees.

Sir: The method of taking contours, as given by Mr. Jno. E. Walker, in Engineering News of April 27, has been used quite extensively by the writer, but a much quicker and as accurate a plan for putting them on the map is used.

The slopes vary from level to 36°. Take a pack of 26 cards, about 1½ x 4 ins.; fasten them together by a brass rivet, and mark them from 1° to 10° consecutively and even degrees above ten. Now lay off the scale and contours on the cards, using the scale the map is drawn to, thus: Take a card of 6° slope and scale 200 ft. to the inch, the contours are 47.6 ft. apart.



To use the cards, go over the map and mark all the elevations taken along the line in pencil, draw in the topography, indicating the arroyo and creeks as usual. To illustrate assume a center elevation of 32.5 at station 396 and use the slopes given.

Sta.	396	+15° / 500	−10° / 200	+5° / 100	Center	−6° / 200	+8° / 400	+12° / 400

On the right of the center line lay off the distances 200, 400 and 400 ft. and mark each point by a pencil dot. Now select the card marked with contours for a slope of 6°, the center elevation given is 2.5 ft. above and below a 5 ft. contour, lay the card to correspond and mark the contours until the 200 ft. is reached. The last contour on this slope is 167 ft. from the center line and the 200-ft. mark is 3.5 ft. below the last contour, which is also noted. The next slope is +8°. Select the card with an 8° slope and place it so the first contour is 3.5 ft. higher than the 200-ft. point and mark the contours until the 400-ft. point is reached. Repeat the operation until all the slopes taken are used.

In a very steep country the measurements are taken on the slope and in this case the other edge of the card is laid out, giving contours and distances reduced to horizontal measurements.

A fair draftsman in a very rough country will plat about 4,000 ft. of railway line per day, and in a comparatively smooth country from 2 to 4 miles per day.

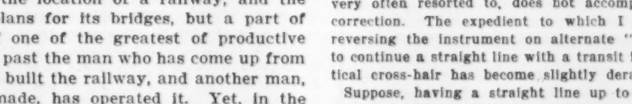
Yours very truly,

Denver, Colo., May 6, 1905. Loc. Engr.

A Common Error in Transit Work.

Sir: It is not my purpose to discuss the various methods of overcoming errors due to imperfect adjustment of instruments, but I will endeavor to show that a method very often resorted to, does not accomplish the desired correction. The expedient to which I refer is that of reversing the instrument on alternate "sights" in order to continue a straight line with a transit in which the vertical cross-hair has become slightly deranged.

Suppose, having a straight line up to a certain point, it is desired to produce the same to any given distance. The transitman plants his instrument over the given point and taking a back sight along the given line, "turns over" and sets a point ahead. Now moving up to this point he takes a back sight at the point just left, but is careful to reverse the instrument so that in setting the next point ahead the error will be thrown to the opposite side of the line. Continuing in this way (the "sights" being practically equal) he produces the line which, though zig-zag, is generally straight and in this respect sufficiently accurate.



But now, coming to the point, though his line is generally straight, it is not a continuation of the given line, but diverges from the same at an angle equal to about one half that of the error in the instrument.

The accompanying sketch will, with a word of explanation, clearly illustrate my meaning. Suppose the line to have been brought up to the point B, and it is desired to continue it to H. The instrument is planted at B and the point C is set, the error being, for instance, to the right. Now setting at C and taking back sight at B, the point D is set; the instrument having been reversed, the error is now to the left of the line C B, along which the back sight is taken.

Continuing in this manner it is evident that the points thus set mark a series of short lines which are, with respect to the desired straight line, alternately divergent and parallel, and the general line, passing for instance through the points B, D, F, etc., will diverge from the desired straight line as above stated.

Thornton, Arkansas, April 5, 1905. D. S. McGlashon.

(We give space to this explanation of a supposed error in the method of "double centering" or "double hubbing," not because there is any error in the method when properly applied, but because our correspondent has not applied it properly. There may be others who likewise believe that the transit should be reversed only at every other instrument station. The proper method of prolonging a line by "double centering" is to take the rear sight, plunge the telescope on

its horizontal axis, and mark a point on the forward "hub," then revolve the transit on its vertical axis, take a new back sight, plunge the telescope again, and mark a second point on the same forward "hub." The prolongation of the line will pass through a point exactly midway between two points found by "double centering."—Ed.)

Further Comments on the Three-Point Problem in Plane-Table Work.

Sir: In your issue of Jan. 26 appeared a discussion of the three-point problem as applied to the plane-table, by several correspondents, to some of whose statements I should like to make reply. It may not be out of place to say that I have used the plane-table in the field for the past twenty years, over a large extent of country and in all conditions of weather, and naturally have had a wide and varied experience in plane-table surveying.

In the first place, the statement made by one of the correspondents that when a point "is without the large triangle it is on the same side of the longest line as the intersection of the other two lines," is not entirely correct. This statement is true when the point is not only outside the triangle but also outside the circle, but when the point lies outside the triangle but *inside* the circle, the statement does not hold good. In that case the position of the point sought in relation to the triangle of error may be ascertained by the following:

Rule 1. When the point sought lies within either of the segments of the circle formed by the sides of the triangles, the line drawn from the middle point lies between the true point and the intersection of the lines from the other two points. When the point sought is without the circle the following rule in regard to the middle point applies:

Rule 2. When the middle point is on the *near* side of the line joining the other two points, the line drawn from the middle point lies between the true point and the intersection of the other two lines. When the middle point is on the *far* side of the line joining the other two points, the true point is upon the same side of the line from the middle point as the intersection of the other two lines.

As will be seen, it is never necessary to apply the rule regarding the most distant point before quoted, as the above middle-point rules apply in all cases outside the triangle, but it is convenient in practice unless as sometimes happens it is difficult to judge which is the most distant point, and in that case the middle-point rules can be applied instead.

The error in supposing that the point sought is on the same side of the line from the most distant point as the intersection of the lines from the other two points, when it is outside of the triangle but not outside of the circle, seems to be quite widespread, has found its way into several publications on the plane-table, and has probably often been the cause of failure in making a three-point location and in acquiring a thorough comprehension of the problem.

Of the several methods of solution of the three-point problem, viz.: (1) by trial, (2) Bessel's method by inscribed quadrilateral, and (3) by use of tracing paper or the geometric method, the method by trial seems to be generally preferred by plane-tablers as more rapid and convenient in practice. It is, in fact, all sufficient, and if thoroughly understood presents no difficulties.

Concerning Mr. Liano's statement that the plane-table is adapted only to rough work, it suffices to say that it is exact to scale, and lines can be drawn on the plane-table sheet as accurately as they can be platted with a protractor. Any plane-tabler, who has seen previously located church spires, flag poles, etc., ten, fifteen and twenty miles away cut exactly by the vertical hair of the alidade when sighted from a station located from comparatively nearby points, can be pardoned for not considering the plane-table an instrument adapted only to rough work.

As regards the accuracy of three-point stations, an experienced plane-tabler has many times located himself from three points, and then the table being in position has been able to pick a far-distant point, as a church spire, tripod or tall tree, previously located, but which he was not able to discover before, and found it to "come in" exactly, thus proving the correctness of his position and the utility and accuracy of the three-point method as well, the only requirement being that the three points from which the station was determined form a well-conditioned triangle.

As regards the distortion of the plane-table sheet, if a good quality of well-seasoned paper be used (two thicknesses with liner between is best), there will be no trouble in that respect as a rule. Plane-table sheets sometimes show no appreciable change in dimensions in many months.

May not the reason for giving only the tracing-paper solution of the three-point problem in some standard works on surveying be the author's lack of familiarity with the practical working of the plane-table? It is certainly possible to explain the subject clearly and without the use of diagrams. Very truly yours,

W. H. Lovell,
Topographer, U. S. Geological Survey.

Ripley, West Virginia, May 16, 1905.

Laying Out City Lots Bounded by Curved Lines.

Sir: I was much interested in reading the article on the "Laying out of city lots bounded by curved and straight lines," by Mr. McCullough, and published in your issue of May 11. Believing the subject to be one of prime importance to both the property owners as well as to surveyors, I desire to discuss the matter briefly.

I quite agree with Mr. McCullough concerning the necessity of more accurate work in laying out and recording plats of subdivisions. The necessity for using well defined and accessible base lines goes without saying. Without complete records of well executed surveys in making such subdivisions, the surveyor who may be called years later, is more or less at sea when he attempts to find the lost lines and corners. Moreover, the probably excessive cost of such subsequent surveys should not be lost sight of.

I must take issue with Mr. McCullough, however, on the methods which he adopts in the marking and recording of curvilinear lines.

The determination of points by latitudes and departures as applied to the plat published with his article would doubtless be a simple matter in execution, so long as the rectilinear intersections were right angles, as his plat shows, but I should certainly not advise the use of this method if the subdivision required the front property line of lots to be placed 310 ft. from the center of a 1° railroad curve and extending along such a curve for over three-quarters of a mile.

The writer has just completed the laying out of a town site having this particular condition to meet, and it was met by the use of the time-honored formula

$$n = \frac{\frac{1}{2} I}{D}, \quad T = \frac{50 \tan \frac{1}{2} I}{\sin D}, \text{ etc.},$$

measuring the curve by chords with the aid of the tape.

I fail to see the advantage of recording the curved length of a line which cannot mechanically be measured on the ground in a practical manner. The value of such surveys, it would seem, would be much enhanced by the readiness with which the dimensions could be marked on the ground itself. With the measurement of curves by their chords, the surveyor can, for the benefit of the property owner if required, stake in the curve using chords 50, 25, 12½, or even 6¼ ft. in length, using a stake that may readily be distinguished from the lot stakes. These stakes can be accurately placed very rapidly and without cumbersome calculations.

The recorded measurement of the shortest distances between two adjacent corners of a lot having a curved line for a boundary would be of some value to the property owner in determining the correctness of his corners independent of a surveyor, while the recorded measurement of a curved line would be to him practically useless, as well as to the surveyor who might try to stake in the curve by latitudes and departures. An exception in the case would be when a reverse or change of curve would occur between lot corners.

I cannot quite agree that it is always possible to obtain good results by finally determining the locations of curved lines, streets, alleys, etc., by means of the topographical map. While a topographical map is of inestimable value, and greatly facilitates such work, no topographical map ever made recorded all the physical features that must be simultaneously dealt with when properly determining general design. The landscape architect must throw mathematics to the dogs for the time being when he finds, as he surely will, that all his efforts in the drafting room will not harmonize with the ground and surroundings as he intended, and his safest resort is to modify his work on the ground itself and measure and record the points and lines afterward.

These and many other points connected with the design and laying out of towns or subdivisions are all of paramount interest to the landscape architect and surveyor.

Burton J. Ashley.

6515 Normal Ave., Chicago, May 18, 1905.

(We append Mr. McCullough's reply to the points raised by Mr. Ashley.—Ed.)

Sir: Replying to criticism made by Mr. Ashley, I wish to state that if he will read my article again he will see nothing was said about the data given for record. The article simply dealt with practical methods of calculation, bearing more particularly upon the manner of connecting the curvilinear lot fronts with the side lines. Many surveyors laying out curved lots seem to be utterly at sea when the question comes up of calculating the lengths of side lines, and their work is frequently done by intersection without calculations to check results.

The drawing given in the paper was simply a reproduction from the working map, and showed how the engineer would keep track of his work as he progressed in his calculations. As a matter of fact, on the record it is my habit to give the central angle; lengths of semi-tangents, length of curve by chords (stating the length of the chords and the length of the sub-chord), always starting with zero at an intersecting side line. Chords can be any length, precisely as Mr. Ashley states. I have generally used 5-ft. or 10-ft. chords. The length of the line placed on the curved front of the lot is always the curved length, regardless of the chord length, but on curves such as laid out for subdivision work, and with the short chords used, the difference is almost negligible. All that is to be borne in mind is that the plat shown is not a copy of the recorded plat.

A statement is made in Mr. Ashley's article referring to a surveyor who might try to stake in a curve by latitudes and departures. The writer does not think that any surveyor would attempt such a foolish thing when he has recorded monuments and all stakes enabling him to stake out the curve in a proper and sensible way. The only use made of latitudes and departures is to calculate the curved connections properly.

Mr. Ashley says that he cannot quite agree with me that it is always possible to obtain the best results by finally determining the locations of the curved lines by means of topographical maps. On reading my article carefully I think he will not find that I differ with him, and I do not rely entirely upon mathematics in endeavoring to harmonize the ground and the wishes of the owner of the subdivision.

A layout on a topographical map is, however, perfectly satisfactory, nine times out of ten, for a man who makes a topographical map of this kind for such a purpose is naturally supposed to use enough common sense and judgment in doing the work to get the results wanted. The writer has made topographical maps and laid out subdivisions on them. He has also gone onto the ground and staked out in advance, without stadia work, certain portions of the ground requiring particular study.

The article to which Mr. Ashley takes exception was necessarily sketchy. A good-sized volume could be written upon such work if one wished to go into all the details connected therewith. Yours truly,

Ernest McCullough

Chicago, Ill., May 24, 1905.

Notes and Queries.

C. A. F., Chicago, Ill., writes:

I would like to know what the experience of the readers of Engineering News has been in the use of a tank for dipping structural steel such as girders, columns, beams, etc., and if experience has proven the method of applying the paint to such work by dipping to be superior to that of painting with a brush, and whether such paint as red lead and oil could be successfully applied by a process of dipping.

We do not see how a red-lead paint could be applied by dipping as the paint sets very soon after mixing. Dipping is largely used in the paint shops of makers of agricultural machinery, light hardware, etc., but the results are generally considered inferior to those obtained by a brush application. The paint is apt to be uneven, being too thick on the lower side where the paint drips off, and air holes are also liable to occur. For the application of a baked japan coating, however, the dipping process has been used with excellent success.

THE DIVISION ENGINEER IN RAILWAY WORK.*

By Willard Beahan, M. Am. Soc. C. E.†

In general, the division engineer in railway work is the engineer nearest in touch with the employees. He has human nature to deal with, and needs most to be human in nature. Said Stephenson, "The most important branch of engineering is the engineering of men."

The theoretical principles of engineering are as broad as the universe; the practical principles may be followed all around the world subject to the laws of climate and of commerce; but human engineering is racial, provincial or individual. It is this last phase of engineering which is latest acquired in the education of engineers for the rank of division engineers. As a qualification in engineering ability, it commands a higher salary than did the added qualification, which in turn made us draftsmen, instrumentmen, or assistant engineers. Too much stress cannot be placed on the value of the study of men when a man is an assistant engineer. When one can do any of the field work and any of the office work on the division, it is most natural to think he can handle the work as a division engineer, but he would probably be unreasonable with foremen and be an expensive man for the company. He knows the theoretical and the practical engineering, but he does not understand human nature, and, therefore, would not succeed in handling men.

We will assume that the division engineer reports directly to the chief engineer and is reported to by the assistant engineers, instrumentmen, rodmen, and other engineering assistants. The clerks of the division office report to him. The roadmasters and master carpenters with their forces, report directly to the division engineer. What duties and what attitude does this require from the division engineer? Toward the chief engineer, his superior, he must have loyalty. This means more than obedience. It is obedience of the heart as well as of the head and hands. No circumstances can justify less. Now loyalty means honesty. Therefore, when your superior asks for your opinion, give it to him. He is entitled to it. He has asked for it. Do not give him a reflection of what you think his opinion to be, just to make yourself "solid"

*Abstract of a paper presented at the meeting of the Western Society of Engineers, Chicago, on May 3.

†Assistant Engineer, Lake Shore & Michigan Southern Ry., Cleveland, O.

with him. That is not honest. If he is competent, he will see through it all. You do not help him any. It is your duty to help hold up the hands of the chief engineer. Try to do that and despise trying to curry favor. Always be respectful to a superior. Your patience will be tried to the limit, but be patient. His clerks will write your letters over his signature, which, placed before a jury of chief engineers, would consign your superior to an asylum, but a division engineer should be above "getting even" with clerks or draftsmen.

The division engineer must be the master of his temper at all times. He must gratefully remember that his is the highest rank surrounded by men who have been specially trained in their specific work. His superior is not so fortunate and has greater trials. Long suffering is not pleasant, but it is, nevertheless, a part of professional training. You do not need to have trying times with but one office now. Promotion will make you worse off, possibly, and just to relieve the strain, see to it that your clerk or your office boy does not write advice to roadmasters, or over your name seek wisdom from bridge men. You have time to go and see, and advise, and inquire, and decide without writing many letters or sending many telegrams. Or, if you have not, send someone to do it for you. Correspondence is essential and unavoidable to a chief engineer. It may be largely or altogether avoided by a division engineer in dealing with subordinates, for he is dependent of necessity upon that human element of which we have spoken. In my experience, the fewer letters a division engineer can write to foremen, roadmasters and master carpenters, the better. Letters can never take the place of meeting a track man or a bridge man on the work and looking it over and talking it over there. If you are not the kind of a man to do that, I think you are not just the kind of a man for a division engineer. You may be able to do better work and of a higher grade, but that particular kind of work you can never do best.

The gangs want to see the "old man" around pretty often. They want him to see how tough a job they have, or how well they are doing the work, or how hot or how cold it is. They will each man work the better for it. Men follow best by sight and learn to love by sight alone. That "absence makes the heart grow fonder," never applied to a pile driver gang. Is it easy and nice driving? They want you to see how fast and how well they are driving the piling. Is it hard and unhandy driving? They want you to see how hard it is to get the piling down and how difficult to get at the piling to keep them in shape at all. Maybe you can suggest something to help. Maybe you can send them a better appliance. In any case you can share the credit, the care and the responsibility, and that alone is a help.

In this connection one scarcely need say that many letters of instruction to assistant engineers and the junior engineering assistant are not in place from a division engineer. If on maintenance, have as many of them as possible work from your own office, and tell them and show them; not write to them. You are the school teacher of the engineering organization. A correspondence school is better than none, but it is not the best. Teaching by personal contact is conceded to be better.

Toward contractors the engineer should show justice tempered with mercy. The division engineer should inculcate that idea in his assistants. An excellent chief engineer laid down this rule to a division engineer on railroad construction: "It is your duty to stand between the contractor and the company, and say what is right in equity." The general clauses of contracts give large powers to the engineer. These are to discipline bad contractors and protect the company from weak ones. They are not intended to be always insisted upon. Never make expense for a contractor which in no way benefits the company. Make the company pay for mistakes of its own employees. Never keep a contractor waiting. Never accept better treatment from him as a division engineer than he gives a rodman. Consider, so far as you can, that all men on the right of way—engineers and contractors—are all under the division engineer, in a way, and make them each and all treat the others well. "Line up" the biggest contractors yourself whenever necessary.

On maintenance, the division engineer has some trials with subordinates. Assistant engineers will get over into the province of master carpenters and roadmasters. Even instrumental men incline to the same fault. Time needed for checking levels and spans will be wasted "chumming" with a foreman and giving him advice. About the third year out of college we feel disposed to instruct the pile driver foreman. About the 23d year, we will be glad to let that foreman do the driving.

Lay out field work on maintenance in trips to cover several pieces of work; each trip with least travel. When that trip is arranged, do not break into it with work that arises at the time. Anticipate work as much as you can. Let some work wait as it can until urgent works takes a party near there. This idea will save on large maintenance divisions about $100 per man per year for traveling expenses, and do more work and do it better. Never start men out so they cannot tell when they will get back. And if, as a division engineer on railway work, you usually work the men nights or Sundays in addition to full week days, you do not know your business. Another man can take your engineering force and do more work for the same money and please both the men and the chief engineer better.

Avoid divided responsibility where you can do so. If you can set apart one piece of work for one assistant engineer, have him do it and let no other man of equal rank go there. Assign work of their kind to instrumentmen and leave them alone responsible to you. Track and bridge men are divided by territory, and keep foremen like divided. Always be able to hold some one man logically and consistently responsible. Give him time and help to do the work. Let him follow his own devices as far as you see you safely can. You see him start; visit the work with him quite often, and occasionally without him. Ask him about progress and cost just to check your own opinion from what you saw there, and to keep him alive to the situation. If he gets into trouble, go out and shoulder the trouble with him, and if serious trouble, be ready to take all responsibility and be on hand for the emergency which you have foreseen or feared for some time. If he does ill, tell him quickly and prove what you say. If he does well, publish it among the men, and tell him, and write the chief engineer, commending him and citing the facts. If you cannot praise a man oftener than you blame him, let him go. And if you never praise him when he deserves it, the time will come when he is deaf to your criticism.

Never think aloud that you know as much about track as a trackman, or as much about bridges as a bridgeman. Listen to their practical opinion and leave them alone to their practical handling of their work. The company is not paying you to be a roadmaster now. It is very hard for young division engineers to curb their knowledge. Just to help yourself to a more correct view, suppose you go to the chief engineer and say a certain bridge is unsafe. When he seems to hesitate to tell you what to do about it, just casually mention, in addition, that the gray haired superintendent of bridges and buildings has also examined that bridge and he, too, thinks it unsafe. Then observe with what alacrity and feeling of relief the chief engineer tells you to rebuild the bridge. As engineers we can never increase our usefulness on maintenance without first having high appreciation of the foremen of maintenance gangs.

It is clearly the duty of the division engineer to work in perfect harmony with each and every division official so far as lies in his utmost power. Be agreeable always. Be a good mixer, but no meddler. Never criticise other departments. Nobody wants to know your opinion on transportation, traffic or motive power. Help the other heads of departments of the division. Make your organization helpful to the whole division, and hold up the hands of the superintendent of the division. Study to make your part of the work contribute all it can to the success of the administration of that superintendent. This is a principle holding true, whether or not you report to that superintendent.

MUNICIPAL IMPROVEMENTS IN SORSOGON, P. I.

By H. L. Stevens.*

Sorsogon is the capital city of the province of the same name, the southernmost province of Luzon. The city is beautifully located at the head of Sorsogon Bay, a body of water six miles wide and fifteen miles long, extending inland from the China Sea.

Filipino cities outside of Manila have no city engineers, but there is in each of the larger provinces a provincial supervisor, an American civil engineer, appointed by the Philippine Commission, whose services in addition to his regular duties are always at the command of such towns as have the funds and also the desire to make public improvements.

Fig. 1. Concrete Curb and Gutter Built by Native Filipinos, Sorsogon, P. I.

*Provincial Supervisor, Province of Sorsogon, P. I.

The city of Sorsogon has nominally 15,000 inhabitants, but in actual size is about as large as an American city of 3,000 people. The city, however, has considerable push and enterprise, and is presided over by a Filipino Presidente or Mayor, who would rival many American municipal officials in intelligence and devotion to duty.

Since the American occupation the city has graveled about 1½ miles of its streets, at a cost of approximately $15,000. It has built several small concrete arch bridges, constructed cement curb and gutter on a portion of its streets, built a diverting dam above the town and taken measures to protect its water supply.

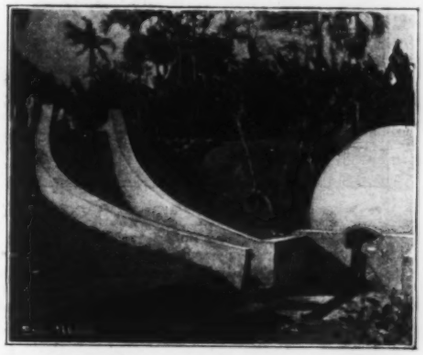


Fig. 2. Concrete Protection of the Main Source of Water Supply for Sorsogon, P. I.

The streets were graveled some three years ago and no definite data as to cost further than the above lump sum are of record. The gravel is river gravel of an excellent quality, which, when it is rolled and packed, gives a smooth, hard surface equal to the best macadam roadway.

The cement curb and gutter is built of this same river gravel, mixed in the proportion of eight parts of small gravel to one part cement. The gravel is screened before using and the coarser stone used as a telford foundation for the gutter. The curb is 16 ins. high and 8 ins. wide, while the gutter is 24 ins. wide. This rather unusual design is adopted for local reasons: The high curb has the effect of forcing the floor levels up to reach the sidewalks and thus gets them off the damp earth where they formerly rested. The broad gutter is designed to carry the storm water due to excessive tropical rains. Some 4,500 ft. of this curb and gutter have been constructed the past season at a cost of 50 cts. gold per lin. ft. The city did its own work with day labor. Fig. 1 is a view of the graveled streets with the cement curbs and gutters.

Fig. 2 shows the measures the city took to protect the spring that furnishes most of the water for the town. This concrete, like the curbs and gutters, is eight parts gravel to one part cement. The total cost of the work was $655.

The diverting dam built to protect the city from the floods of the Sorsogon River is 175 ft. long and consists of two parallel concrete walls 6 ft. apart, with the space between filled with loose gravel. The total cost of this work was $900 gold.

All of the above work was performed by Filipino workmen with native foremen. The men were hired and controlled by the Provincial Supervisors' office, but were paid by the city. The wages paid were 50 cts. gold per day for laborers and $1 gold per day for foremen. The city now has under construction a 50-ft. span reinforced concrete arch across one of the small rivers of the town, and contemplates building a large amount of curb and gutter the coming year. Under the present laws it is impossible for a municipal government to incur a bonded indebtedness, so that all improvements are paid for as they are made.

WRECK OF THE PORTAGE CANAL DRAW-BRIDGE.

As was briefly noted in our issue of May 4, the swing span of the bridge over the Portage Canal at Houghton, Mich., was struck by a steamer and knocked off the pivot pier on April 15. It was a double-deck lattice-truss bridge, built by the Lassig Bridge Co., of Chicago, and carried a rail-

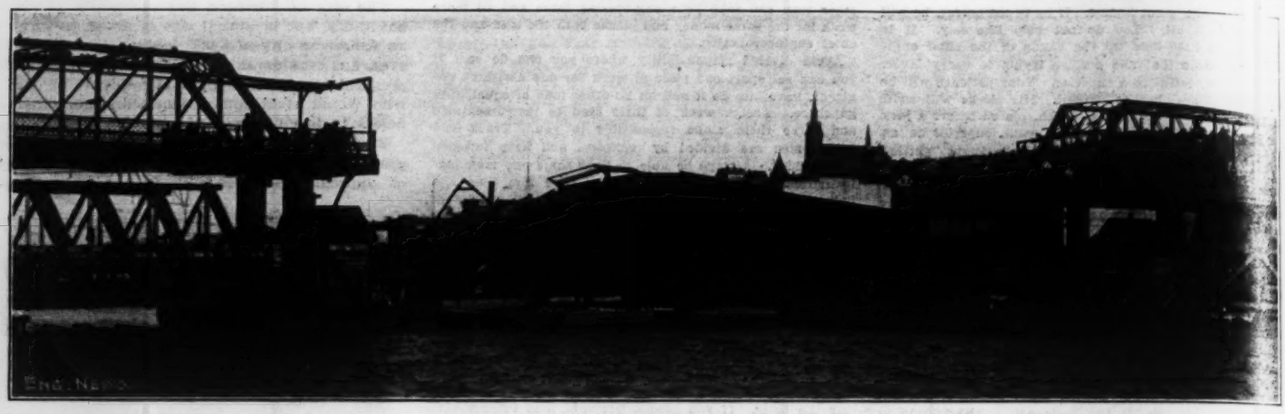


FIG. 1. VIEW OF PORTAGE LAKE SWING BRIDGE, OVERTURNED BY COLLIDING STEAMER ON APRIL 15, 1905.
(View from Hancock Side, Houghton in Background.)

way on the lower deck and a highway with electric car tracks on the upper deck. The following notes, for which we are indebted to Mr. C. H. Hoyt, Instructor in Civil Engineering at the Michigan College of Mines, Houghton, Mich., give some more detailed information about the accident.

The western arm of Portage Lake, forming part of the passage through Keweenaw Peninsula, by way of which most of the long-distance traffic of Lake Superior goes, is crossed by a combination railway and highway bridge, which except in the draw span consists of two superimposed bridges. The upper is a steel highway bridge, carrying a double-track electric street railway, while the lower bridge is partly a timber Howe-truss and partly a riveted steel truss bridge carrying a single railway track used by the Copper Range R. R. and the Duluth, South Shore & Atlantic R. R. The drawspan in the bridge is a steel pin-connected double-deck swing span, crossing channels respectively 62 ft. and 64 ft. in the clear. The total length of the drawspan is about 160 ft. Through this draw passes the immense traffic of coal, iron, grain and lumber between Duluth and Superior on the west and Buffalo and other ports of the lower lakes on the east, and also a part of the copper shipments from the copper regions near Houghton.

On Saturday, April 15, 1905, the steamer "Northern Wave," of the Mutual Transit Co., the second or third vessel to arrive at the draw this season, loaded from the Duluth side for the lower ports, ran into and completely wrecked the drawspan. There was a misunderstanding of signals between the boat and the bridge-tender, and the latter was finally unable to open the draw in time to avert the accident.

The accompanying views, showing the bridge after the accident, exhibit its general construction. The foundation for the draw span is an octagonal concrete center pier about 26 ft. across, surrounded by a timber protection and cutwater 200 ft. or more in length. The pivot base casting was anchored in the concrete with six 1¼-in. bolts, all of which were sheared off at the top of the concrete. The casting was pushed about one-fourth the distance across the pier, where the bottom flange crushed as indicated by the sketch in Fig. 4. The original position of the base casting is beneath the man standing on the radial roller rods in Fig. 3.

The view Fig. 1, taken from the Hancock side, with Houghton in the background, shows the wrecked span resting on the timber cribbing around the center pier. The boat approached the draw where the two scows are seen between the cribbing and the end pier to the left. To provide for temporary railroad crossing after the accident, two scows were placed in the draw on either side of the center pier, and upon these four scows, the center pier and the two end piers was placed a cribwork of square timbers up to the required height for the track. Owing to the position of the wrecked span the track had to be placed a few feet toward one end of the scows from their center. A few cars were put across this pontoon bridge on Monday, two days after the wreck, but a locomotive tender and car of rails proved to be too heavy a load and went down in the draw on the Hancock side. This plan for transferring cars was then abandoned.

Fig. 1 also indicates partially the comparative injury to the span due to the fall alone and to the fall combined with the blow from the boat.

Fig. 2, a view taken from the Houghton side, shows the curvature the span received due to its fall, and also shows the operator's crushed house from which he was taken after the accident. The

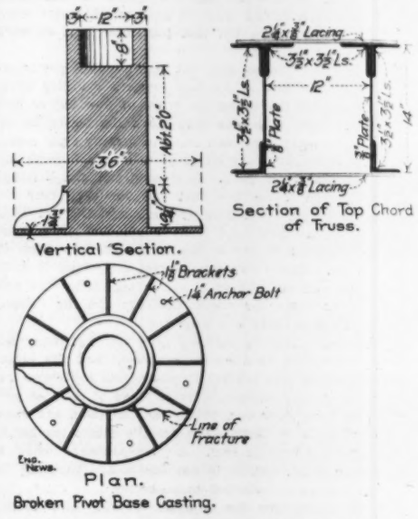


Fig. 4. Sketch of Broken Pivot Base Casting, and Chord Section of Truss; Portage Lake Swing Bridge.

FIG. 2. VIEW OF OVERTURNED PORTAGE LAKE SWING BRIDGE FROM HOUGHTON SIDE.

end of the span shown in this view caught on the timber protection for the end pier, and possibly saved the span from curving deeper into the water. The two tall buildings on top of the hill in Fig., 2 are combined shaft and rock houses of the famous Quincy Copper Mine, No. 5 being at the left and No. 7 at the right; the latter has the deepest shaft of this mine, something over a mile in depth on the slope.

A good indication of the amount of injury caused by the impact of the boat is given in the view Fig. 3. The chords of the truss are built-up sections of plates and angles, forming two I-sections latticed top and bottom, about as sketched in Fig. 4. These were bent nearly at right angles, and pushed over against the other truss.

This bridge is owned jointly by Houghton County, the Duluth, South Shore and Atlantic R. R. and the Copper Range R. R. A meeting of the interested officers and officials of the Government Engineer Corps was called soon after the accident, at which it was decided that an entirely new draw span would have to be built. This being the case, advantage was taken of the opportunity to widen the draw, which will doubtless prove an interesting problem and for which plans are being prepared.

It was necessary to clear the navigation channel as soon as possible, and a contract was let to the Wisconsin Bridge and Iron Co. to remove the

FIG. 3. NEAR VIEW OF HANCOCK END OF OVERTURNED PORTAGE LAKE SWING BRIDGE.
(The white cross shows where the steamer struck the bridge.)

wreck. The work began the following Tuesday, and was creditably executed, the Houghton side of the draw being cleared in six days. This work was carried out as follows: A breast derrick was set on the timbering around the end pier, taking a hitch on the under truss to prevent its going deeper into the water and to raise the submerged portion as it was lightened. Several bridge men were set to work cutting out rivets, and a stiff-leg derrick was then set on the temporary track and scows in the Houghton draw in such position that the boom would reach to the span and land its load on cars on the temporary track. The highway floor and its beams were taken off first, the web members of the upper truss next; then the bottom chord floor beams and stringers. Then a part of the top chord of the upper truss was taken off and the lower chord was cut off to clear the draw. The submerged part of the lower truss had then been raised to the surface of the water and was taken apart. The task of clearing the Hancock draw has been carried on in much the same way, but has been more difficult work owing to the end of the span being submerged deeper, and because of the mangled and twisted condition of the truss members due to the blow from the boat.

For transportation between the two towns a ferry service has been provided by tugs and scows, which causes little inconvenience to persons and teams, and three freight cars are taken across at a time on another scow.

ENGINEERING MATERIAL PRICES.

(These prices will appear in the first or second issue of each month.)

TRACK FASTENINGS—
Chicago—at mill—Angle bars, 1.40 to 1.50 cts.; spikes, 1.75 to 1.85 cts.; track bolts, 2.40 to 2.50 cts.

RAILS, STEEL—
New York—at mill—New standard sections, $28; light rails, $23 to $25; old iron, f. o. b. New York, $19 to $20; old steel, rerolling lengths, $14.50 to $15; old steel, short pieces, $14 to $14.50; relayers, $20 to $21.
Chicago—at mills—New, $28, standard sections; light rails, $24 to $27; old iron, $18 to $18.50; old steel, 4 ft. and over, $13.50 to $14; old steel, less than 4 ft., $13 to $13.50; heavy relayers, $22.25 to $22.75; heavy relayers for side tracks, $19.50 to $20.
Pittsburg—at mill—Standard sections, $28.

STRUCTURAL MATERIALS—
New York—at tidewater—Beams, channels, angles and zees, 1.74½ to 1.84½ cts.; tees, 1.79½ to 1.89½ cts.; bulbs, angles and deck beams, 1.84½ to 1.94½ cts.
Chicago—Beams and channels, 3 to 15-in., inclusive, and angles 3 to 6-in., ¼-in. and heavier, 1.76½ cts.; tees, 3-in. and over, 1.81½ cts.
Pittsburg—Beams and channels, up to 15-in., 1.60 cts.; over 15-in., 1.70 cts.; angles, 3 × 2 × ¼-in. thick up to 6 × 6-in., 1.60 cts.; angles, 8 × 8 and 7 × 3½ in., 1.70 cts.; zees, 3-in. and larger, 1.60 cts.; tees, 3-in. and larger, 1.65 cts.

PLATES AND SHEETS—
New York—at tidewater—Sheared plates, tank, 1.74½ to 1.84½ cts.; flange, 1.84½ to 1.94½ cts.; marine, 1.94½ to 2.04½ cts.; fire box, 1.94½ to 2.50 cts.
Pittsburg—Tank, ¼-in. thick, 6¼ to 14-in. wide, 1.50 cts. at mill, Pittsburg; flange and boiler steel, 1.60 cts.; marine and ordinary fire box, 1.70 cts., at mill, Pittsburg; locomotive fire box, 2 cts.

MERCHANT STEEL—
Chicago—Machinery, smooth finished, 1.91½ cts.; tire, smooth finished, 1.86½ cts.; railway spring, 1.86½ cts.; crucible tool, 6½ to 8 cts.; special tool, 13 cts. and up.
Pittsburg—Railway spring steel, 1.70 cts.; smooth finished tire, 1.70 cts.; smooth finished machinery steel, 1.70 to 1.75 cts.; crucible tool steel, ordinary grades, 5¾ to 8 cts.; extra grades, 10 cts. and up.

Iron—
Pig Iron:
New York—No. 1 X Foundry, $17 to $17.25; No. 2 X Foundry, $16.50 to $16.75; No. 2 Plain, $16 to $16.25; Gray Forge, $14.75 to $15.25; Basic, $16.25 to $16.75; Southern No. 1 Foundry, $17 to $17.25.
Chicago—Lake Superior Charcoal, $17.50 to 18; Northern Coke Foundry, No. 1, $17.75; Northern Coke Foundry No. 2, $17.25; Northern Coke Foundry No. 3, $16.75; Northern Scotch No. 1, $18; Jackson Co. and Ky. Silvery, 6% Silicon, $19.80; Jackson Co. and Ky. Silvery, 7% Silicon, $20.30; Jackson Co. and Ky. Silvery, 8% Silicon, $20.80; Jackson Co. and Ky. Silvery, 10% Silicon, $21.80; Alabama Basic, $17.65; Virginia Basic, $17.65; Ohio Strong Softeners, No. 1, $18.30; Ohio Strong Softeners, No. 2, $17.80; Southern Silvery, 4 to 6% Silicon, $18 to $19; Southern Coke, No. 1, $17.15 to $17.40; Southern Coke, No. 2, $16.65 to $16.90; Southern Coke, No. 3, $16.15 to $16.40; Southern Coke, No. 4, $15.90 to $16.15; Southern Coke, No. 1, Soft, $17.15 to $17.40; Southern Coke, No. 2, Soft, $16.65 to $16.90; Southern Gray Forge, $15.65 to $15.90; Southern Mottled and White, $15.40 to $15.65; Malleable Bessemer, $17.25; Standard Bessemer, $17.80 to $18.30.
Pittsburg—Foundry iron, Northern, No. 2, $15.50 at Valley furnace; $16.35 at Pittsburg; Northern forge, $14.65 to $14.75 at Valley furnace; $15.50 to $15.60 at Pittsburg; Bessemer and Basic, $15.25 to $15.50 at Valley furnace; $16.10 to $16.35 at Pittsburg.
Cast-Iron Pipe:
New York—Carload lots, net tons, 6 to 8 ins., at tidewater, $28.
Chicago—4-in. water pipe, $29; 6-in. and larger, $28, with $1 extra for gas pipe.

MISCELLANEOUS MATERIALS—
Asphaltum:
Ventura and other California asphalts, $20 to $21 per ton at New York; Trinidad refined, $25 to $30 per ton; Venezuela asphalt, $25 to $30 per ton; Bermuda asphalt, $25 to $30.
Cement:
Rosendale, in wood, $1; Portland, domestic, $1.70 to $1.80; Foreign brands, $2.25 to $2.50.
Copper:
Lake, 15 cts.; electrolytic, 15 cts.; casting, 14.75 cts.
Lead:
New York, spot, 4.50 to 4.60 cts.
Spelter:
New York, spot, 5.40 to 5.50 cts.
Tin:
New York, spot, 29.87½ to 30.25 cts.

LUMBER—
New York, wholesale prices:
Piling—Spruce, ordinary cargoes, 6 to 7 cts.; oak, 14-in. butt, 40 to 50 ft., 19 cts.; 50 to 55 ft., 22 cts.; 55 to 60 ft., 23 cts.; 60 ft. and up, 25 cts.; pine, 60 to 65 ft., $8.50; 70 to 75 ft., $10.50; 80 ft. and up, $16.
Railroad ties—Yellow pine, 6 × 9 ins. × 8 ft., 58 to 59 cts.; 6 × 8 ins. × 8 ft., 53 to 54 cts.; 7 × 9 ins. × 8 ft., 64 to 65 cts.; 7 × 8 ins. × 8½ ft., 59 to 61 cts.; 7 × 9 ins. × 8½ ft., 64 to 66 cts.

THE PHILADELPHIA GAS LEASE EXTENSION ordinance has been killed by Mayor Weaver and the citizens of Philadelphia. Following his announcement that he would veto the ordinance, the mayor removed from office Peter E. Costello, Director of Public Works, and David J. Smyth, Director of Public Safety, and appointed in their places A. Lincoln Acker and Col. Sheldon Potter. An injunction from a lower court temporarily restrained the new appointees from exercising the duties of their offices, but the State Supreme Court reinstated them, pending a trial under its jurisdiction (set for May 29 and adjourned to May 31). Meanwhile, the people of Philadelphia, by public and private action, raised such a protest against the gas lease extension and the machine and corporate interests back of it, and brought so much pressure to bear upon members of councils, that up to noon on Saturday, May 29, 34 members of the two branches had promised that on receipt of the expected veto, June 1, they would join the twelve men who voted against the lease, two weeks before. Early on the afternoon just named, Mr. Thos. Dolan, President of the United Gas Improvement Co., made public a letter addressed to councils announcing that, even should the ordinance become a law, the company would not accept it, since "the manner in which the whole subject has been treated induces this company to believe that the community is opposed to any extension of the gas lease upon any terms." The "organization," it is reported, have seriously considered bringing impeachment proceedings against the mayor, but he has boldly announced that:

My unalterable purpose has been to defeat the iniquitous gas lease proposition, and to free the city from the thraldom of boss rule.

My enemies may throw me out of office, if they can, but I have gripped my arms about the pillars of their temple, and if I go down I shall drag down with me the ruins of the structure they have reared.

No human power can now deter me from fighting to a finish.

In line with the mayor's broader purpose of freeing "the city from the thraldom of boss rule" is an attempt now being made to raise by popular subscription no less than $1,250,000 for the political cleansing of Philadelphia.

Since the foregoing statements were written the forces arrayed against the mayor and the people have given up the fight.

THE THEBES CANTILEVER BRIDGE over the Mississippi River, which was described and illustrated in our issue of May 11, was formally opened to traffic on May 25, although it had, in fact, been in use for a few weeks. Special trains, with engineers, railway officials and prominent business men, were run from Chicago and St. Louis. The ceremonies consisted in first running the two trains across the bridge, side by side, while a band was stationed on a gondola attached to the St. Louis train. They then returned to the Illinois side, and the party assembled around a platform, where speeches were made by Mr. F. H. Britton, President of the Southern Illinois & Missouri Ry. Co., owning the bridge; Mr. A. G. Cochran, General Counsel of the Missouri Pacific Ry.; Mr. W. G. Fordyce, of St. Louis; Hon. J. W. Folk, Governor of Missouri; Mr. W. J. Calhoun, of Chicago; and Professor C. M. Woodward, of Washington University. The latter referred to the important part played by the engineer in the railway development of the country, especially in the construction of great works of this kind, and congratulated the designers and engineers of this bridge, Mr. Alfred Noble and Mr. Ralph Modjeski (both of whom were upon the platform), on the successful completion of the enterprise. One of the speakers pointed out that the five railway systems now under contract to use this bridge have an aggregate length of 25,000 miles. At the close of the addresses, two long rows of heavy freight engines passed over the bridge side by side, stopping at the middle to announce the opening of the bridge by prolonged whistling.

THE INSTALLATION OF WATER METERS AT CHICAGO is strongly urged by Mr. John Ericson, City Engineer, in an official report just made public. Mr. Ericson points out the magnitude of the water-works extensions in progress and projected, the great water waste known to exist, and makes a strong plea for curtailing the waste by the use of meters.

PERSONAL.

Mr. D. A. Brotherton has been appointed City Engineer of Escanaba, Mich.

Mr. Clark G. Anderson, formerly of Peoria, Ill., has been appointed City Engineer of Moline, Ill.

Mr. Charles A. Barton has been elected Engineer and Secretary of the County Levee Commission of Memphis, Tenn.

Mr. W. L. Kinsell, Chief Draftsman of the Northern Pacific Ry., has been appointed Mechanical Engineer, with headquarters at St. Paul, Minn.

Dr. Myron S. Falk has opened an office for the general practice of civil engineering at 60 Wall St. Dr. Falk will still retain his connection at Columbia University.

Mr. W. L. Hemphill, formerly with R. Jesty & Co., Greenwood, Miss., has accepted a position in the engineering corps of the Yazoo-Mississippi Levee District at Clarksdale, Miss.

Mr. W. D. Lovell, M. Am. Soc. C. E., of Minneapolis, Minn., is delivering a series of lectures on "Water Supply" to the candidates for degrees from the Engineering Department of the State University of Iowa.

Mr. George A. Ralph, of Crookston, Minn., has been re-

elected State Drainage Engineer of Minnesota. The State Drainage Board has appointed Mr. John Abercrombie, of Alexandria, Minn., Topographical Engineer.

Mr. D. H. McDougall, for the past two years Field Engineer for the Dominion Iron & Steel Co., at Sydney, N. S., has been promoted to the position of Superintendent of Ore Mines for the same company, at Wabana, Newfoundland.

Mr. James Dalrymple, General Manager of the street car system of Glasgow, Scotland, who is to advise Mayor Dunne, of Chicago, in regard to the municipalization of the street railways of that city, arrived at New York May 27.

Mr. L. K. Sherman has been appointed Resident Engineer in charge of construction of the power house on the water-power development of the Chicago Drainage Canal, which is being undertaken by the Sanitary District of Chicago.

Mr. A. W. Jones has been appointed Assistant Engineer of the Missouri Pacific Ry., in charge of construction, with headquarters at Keener, Ark. Mr. Jones formerly was connected with the New York Central & Hudson River R. R., at New York.

Mr. R. W. Hebard, for several years connected with the Chicago, Rock Island & Pacific Ry., has resigned to accept a position as Assistant Engineer on the Panama Canal, and will serve under Mr. W. E. Dauchy, Division Engineer, on the Culebra work.

Mr. Alfred L. Hartridge, Chief Engineer of the Kansas City, Burlingame & Western R. R., and Chief Engineer of the Union Depot, Bridge & Terminal R. R., formerly with headquarters in the Temple Block, Kansas City, Mo., has gone to Guatemala, Central America, to take charge of bridges and masonry on the Guatemala Northern R. R. Mr. Hartridge will have his headquarters at Sanarate.

Brigadier-General Henry L. Abbott, U. S. Corps of Engineers, retired; Mr. Isham Randolph, M. Am. Soc. C. E., Chief Engineer, Sanitary District of Chicago, and Mr. Herman Schussler, Chief Engineer, Spring Valley Water Works Co., of San Francisco, Cal., have been appointed consulting engineers to the Isthmian Canal Commission.

Mr. F. Neper has been appointed Principal Assistant Engineer of the Missouri Pacific Ry., with headquarters at St. Louis, Mo., and will have supervision over surveys and new work other than bridge building and signal work, reporting to the engineer of maintenance of way. Mr. J. O. Potts has been appointed Assistant Engineer, Maintenance of Way, with supervision over methods and materials in track, bridges and building.

Mr. John W. Emig, formerly a structural engineer in the Bridge Department of the Chicago & Northwestern Ry., has been elected Treasurer of the Globe Iron Works, of Chicago, Ill., and will take an active interest in the management of its affairs. The above firm was one of the first to establish the structural steel business in Chicago. Mr. Emig was graduated from the Rensselaer Polytechnic Institute of Troy, N. Y., in 1898.

Obituary.

Andrew Jay C. Foye, Director and the New York Manager of the Joseph Dixon Crucible Co., died May 26 at his home in New York. At the time of his death he was President of the Standard Graphite Co. He was 72 years old.

Royal M. Bassett, for a number of years President of the Utah Northern R. R., and Director of the Naugatuck R. R., died May 25 at his home in Derby, Conn. For half a century he had been a prominent iron manufacturer. He was born in 1828.

William C. Jutte, a capitalist of Pittsburg, Pa., died May 24 at Atlantic City, N. J., from a self-inflicted pistol shot wound. Mr. Jutte was interested in the Monongahela & Western Dredging Co., the Jutte & Foley Contracting Co., and the Pittsburg Gravel & Dredging Co., of New Orleans. He was 44 years old.

Raymond W. Smith, Superintendent of Construction on the Torresdale filtration plant of Philadelphia, for D. J. McNichol, contractor, was accidentally thrown from his horse May 22, and fatally injured. Mr. Smith was a student for several years at Lehigh University, and had traveled extensively through Venezuela and Mexico, examining mining properties. He had been engineer for the Mack Paving Co. and the Asphalt Co., had constructed 113 miles of road in Long Island, and had been engineer for the National Contracting Co. in the erection of the power house for the Niagara Falls Power Co.

Col. Wm. M. Patton, Dean of the Department of Engineering at Virginia Polytechnic Institute, died May 26 in New York City, where he had gone for treatment. Col. Patton was the author of a work on foundations, also of a treatise on civil engineering, and had contributed a number of articles to Engineering News. He was well known as a civil engineer, having been at one time Chief Engineer of the Mobile & Ohio R. R., and of the construction of the Susquehanna River bridge of that road. He was for a number of years Professor of Engineering at Virginia Military Institute. For the last five or six years he has been Professor of Civil Engineering at the Virginia Polytechnic Institute, and last year was elected to the position of Dean of the Department of Engineering.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
June 6, 7, 8, 9, 1905. Annual spring convention, at Scranton, Pa. Secy., F. R. Hutton, 12 West 31st St., New York, N. Y.

AMERICAN FOUNDRYMEN'S ASSOCIATION.
June 6 to 9, 1905. Annual convention in New York. Secy., Richard Moldenke, Watchung, N. J.

MASTER CAR BUILDERS' ASSOCIATION.
AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.
June 14-21, 1905. Annual meeting at Manhattan Beach, N. Y. Secy., J. W. Taylor, The Rookery, Chicago, Ill.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
June 19 to 23, 1905. Annual convention at Asheville, N. C. Secy., R. W. Pope, 95 Liberty St., New York, N. Y.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
June 20 to 23. Annual convention at Cleveland, Ohio. Secy., Charles Warren Hunt, 220 West 57th St., New York, N. Y.

ASSOCIATION OF TRANSPORTATION AND CAR ACCOUNTING OFFICERS.
June 20, 21, 1905. Annual meeting at Toronto, Ont. Secy., G. P. Conard, New York, N. Y.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.
June 28, 29, 1905. Annual meeting at Atlantic City, N. J. Secy., Prof. M. S. Ketchum, Boulder, Colo.

AMERICAN SOCIETY FOR TESTING MATERIALS.
June 28, 1905. Annual meeting at Atlantic City, N. J. Secy., Prof. Edgar Marburg, Philadelphia, Pa.

PACIFIC COAST ENGINEERING CONGRESS.
June 29 to July 1. At Portland, Oregon. Otto von Geldern, San Francisco, Cal., or Milnor Roberts, Seattle, Wash.

PACIFIC NORTHWEST SOCIETY OF ENGINEERS.
June 29 to July 1. Annual convention at Portland, Oregon. Secy., Milnor Roberts, Seattle, Wash.

LEAGUE OF AMERICAN MUNICIPALITIES.
August 23 to 25. Annual meeting at Toledo, O. Secy., J. McVicar, Des Moines, Ia.

INTERNATIONAL ASSOCIATION OF MUNICIPAL ELECTRICIANS.
August 29, 30, 31, 1905. Annual convention at Erie, Pa. Secy., F. P. Foster, Corning, N. Y.

AMERICAN PUBLIC WORKS ASSOCIATION.
August 30, 31, 1905. Annual meeting at Chattanooga, Tenn. Secy., W. H. Flint, Chattanooga, Tenn.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS.
Sept. 5 to 7. Annual meeting at Montreal, Canada. Secy., Geo. W. Tillson, Brooklyn, N. Y.

ROADMASTERS & MAINTENANCE OF WAY ASSOCIATION.
Sept. 12, 14. Annual meeting, at Niagara Falls, N. Y. Secy., C. E. Jones, C., B. & Q. Ry., Beardstown, Ill.

NATIONAL GOOD ROADS CONVENTION.—The fifth annual good roads convention is to be held in the auditorium at the Lewis and Clark Centennial Exhibition, Portland, Oregon, on June 21 to 25, 1905.

MEMPHIS ENGINEERING SOCIETY.—The fourth annual meeting of this society will be held at Memphis, Tenn., on June 13, 1905. The programme for this meeting consists of a railway excursion in the morning to the Nonconnah Yards of the Illinois Central Ry. and around the city, an afternoon steamer trip to Hopefield Bend and the Memphis Bridge, a business meeting at 8 p. m. in the society rooms, 127 Madison St., and a banquet at 9.30 p. m. at the Sazerac Cafe. Secy., C. C. Pashby.

WESTERN RAILWAY CLUB.—At the meeting on May 20, a paper on "Electricity on Steam Railways" was presented by Mr. C. F. Street, of the Westinghouse Electric & Mfg. Co. Officers for the ensuing year were elected as follows: President, J. A. Carney; Vice-Presidents, H. T. Bentley and C. A. Seley; Treasurer, P. H. Peck; Secretary, J. W. Taylor. The club's headquarters have now been transferred to 390 Old Colony Building, Chicago, and provide better accommodation for the David L. Barnes Memorial Library.

CEMENT BLOCK MACHINE MAKERS' ASSOCIATION.—During the past two months an active effort has been made to interest the builders of concrete block machines in the matter of forming an association for technical discussion. The replies have been uniformly favorable, and it is therefore arranged that the meeting for organization will be held at the Great Northern Hotel, Chicago, Ill., on June 27 and 28, 1905. Assurances are at hand that the meeting will be very largely attended. The preliminary arrangements are being made by Mr. S. L. Wiltse, of the Cement Machinery Co., Jackson, Mich.

ASSOCIATION OF RAILWAY TELEGRAPH SUPERINTENDENTS.—The twenty-fourth annual meeting was held at Chattanooga, Tenn., May 17 and 18. The three principal papers were as follows: "Railway Telephone Service and Cost of Line Construction," by F. T. Fowle; "High Tension Wires on Railway Right-of-Way," by W. J. Camp; "Overhead Breaks and Their Remedy," by Wm. Maver. A committee was appointed to request the American Railway Association to assist in the passage of State laws to prevent the erection of high-tension lines over their right-of-way. Another committee was appointed to consider remedies for the breaks in telegraph lines caused by snow and sleet. The officers elected are as follows: President, E. E. Torrey; Vice-President, E. A. Chenery; Secretary, P. W. Drew (Wisconsin Central Ry.), Milwaukee, Wis. The next meeting will be held at Denver, Colo., in June, 1906.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.—The thirteenth annual meeting of the Society for the Promotion of Engineering Education will occur at Atlantic City, N. J., on Wednesday and Thursday, June 28 and 29, 1905. The meeting will be held in affiliation with the American Society for Testing Materials. The session on Thursday evening will be a joint session. A full program has been arranged, details of which will be furnished later. The headquarters for the meeting will be at Hotel Chalfonte.

The membership of the Society for the Promotion of Engineering Education now numbers 379, representing 96 colleges and institutions teaching engineering. The twelfth annual report has just been issued; it may be obtained from the Engineering News Publishing Co., 220 Broadway, New York, for $2.50 per volume. Secy., Prof. M. S. Ketchum, Boulder, Colo.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—As already announced, the annual summer convention of the society will be held at Cleveland, O., on June 20 to 23, 1905, with headquarters at the Hollenden Hotel. The rate of one-and-one-third fare on the certificate plan has been given by the railways of the Central and Trunk Line Passenger Associations. A special train from New York to Erie, furnished free of charge by the Erie Ry., will leave New York City at noon June 19. The program at Cleveland includes the following items: Tuesday, June 20, 10 a. m., Address of Welcome by Mayor T. L. Johnson; Response, and a business session. At this session routine business will be transacted, the question of formation of local associations of the society will be considered, and means will be discussed for enabling the society to appoint members of public technical commissions where such action is requested by public authorities. Tuesday afternoon, a drive around the city. Tuesday, 8.30 p. m., a session at which President C. C. Schneider will deliver the annual address. Wednesday, 10 a. m., addresses on various features of technical interest in and near Cleveland; in the afternoon visits will be made to various plants described in the morning's addresses. Wednesday evening an entertainment will take place at the Hollenden Hotel. Thursday morning is reserved for a probable additional session of the society; on the evening of the same day a reception, with dancing, is to be given at the Chamber of Commerce. Friday, June 23, will be given up to an all-day excursion to Lorain, where several works will be visited. Secy., Charles Warren Hunt, 220 W. 57th St., New York.

AMERICAN FOUNDRYMEN'S ASSOCIATION.—The program for the eighth annual convention (New York City, June 6 to 8, 1905) includes five sessions, respectively morning and afternoon of June 6 and 7, and the morning of June 8. The first, second and fifth sessions take place at Grand Central Palace, 43d St. and Lexington Ave., while the third and fourth are at Columbia University, 116th St. and Amsterdam Ave. The following papers will be presented: "Notes on Pipe Foundries, and Suggestions on Metal Mixers for Foundry Purposes," by J. B. Nau (New York); "Notes on Retort-Coke Melting Ratios," by C. M. Schwerin (Milwaukee, Wis.); "Foundry Facings," by E. D. Frohman (Pittsburg, Pa.); "Needed in the Business," by B. D. Fuller (Allegheny, Pa.); "Blowers, Piping and Cupolas at the Plant of the Michigan Stove Co.," by W. J. Keep (Detroit, Mich.); "Production Costs," by E. M. Taylor (Boston, Mass.); "Accounting," by K. Falconer (Montreal, P. Q.); "Cost-Keeping in the Foundry," by R. W. MacDowell (Uniontown, Pa.); "Development of the American Pig-Iron Warrant System for Foundry Use," by G. H. Hull (New York, N. Y.); "Some Thoughts on American Foundry Practice," by J. D. Burns (Plainfield, N. J.); "Practical Brass Founding," by C. Vickers (Milwaukee, Wis.); "A Modern Method of Venting Cores," by J. A. Murphy (Franklin, Pa.); "Things We Need in the Foundry," by D. Spence (Chicago, Ill.); "The Use of Plaster of Paris in the Foundry," by E. B. Gilmour (Peoria, Ill.); "Melting Steel with Iron," by R. P. Cunningham (Holyoke, Mass.); "A Simple Method of Molding Propeller Wheels," and "A Successful Foundry Combination," by A. M. Loudon (Elmira, N. Y.); "Making a Molder," by H. M. Lane (Cleveland, O.); "American Molding Sands," by Prof. H. Ries (Ithaca, N. Y.); "The Work of the American Society for Testing Materials in Connection with the Foundry Industry," by C. B. Dudley (Altoona, Pa.); "Progressiveness," by S. H. Stupakoff (Pittsburg, Pa.); "Shot Iron," by W. W. Sly (Cleveland, O.); "Fan and Blower Tests," by H. E. Field (Pittsburg, Pa.); "Aluminothermics," by W. M. Carr (New York, N. Y.); "The Use of Thermite in a Railroad Shop," by J. F. Webb (Elkhart, Ind.); "The Repair of Driving-Wheels by Thermite," by G. N. Prentiss (Milwaukee, Wis.); "Core Sands," by J. S. Robeson (Camden, N. J.); "The Variation of the Properties of Alloys," by P. Longmuir (Sheffield, England); "Foundry Facings, Their Properties and Analysis," by W. G. Scott (Racine, Wis.); "Physical Properties of Cast Iron, as Influenced by the Carbon Condition," by J. J. Porter (Chicago, Ill.); "The Effect of Manganese in Low Silicon Cast Iron," by H. C. Loudenbeck (Wilmerding, Pa.); "A Foundry Laboratory of South Germany," by C. C. MacPherran (Milwaukee, Wis.); "Comparison of Various Methods for the Determination of Sulphur in Pig Iron," by A. Hart, Jr. (State College, Pa.); Report on the Proposed Standard Method for Determining Silicon in Pig Iron; "Foundry and Pattern Shop Standards," by W. H. Parry (Brooklyn, N. Y.); "Care and Storage of Patterns," by H. M. Lane (Cleveland, O.); "Better Conditions in the Pattern Shop, an Experiment that Succeeded," by J. L. Gard (Denver, Colo.). On Thursday afternoon the association will visit the works of the International Steam Pump Co., at Harrison, N. J.